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FRAGMENTATION IN RESEARCH

Last week we had the pleasure of attending an Open Day at the British Hydromechanics Research Association's laboratory at Harlow. This Association is, relative to many others, very young. The laboratory was opened as recently as 1951. But in the short space of four years it has so well proved its value that its annual income from industry is steadily increasing and the space available at the laboratory is already showing signs that it will soon be overtaxed. It would be too much to expect in the short space of four years that the Association should be able to point to many major achievements. Yet one of the devices developed already shows high promise. It is that for the water carriage of coal, involving means of pumping the water to the pressure necessary, for example, to discharge coal to the surface from a pit bottom, and the introduction of coal into the water under pressure. A three-cylinder coal feeder was on view designed to inject 50 to 100 tons of coal an hour into a high pressure water pipe at the bottom of a 500-foot mine. This machine is to be installed at a colliery in the East Midlands. Again, like so many other research bodies, the Hydromechanics laboratory has found that there are a number of relatively simple studies that one might well have expected to have been undertaken long ago but which no one apparently has bothered to undertake before. For example, faulty design of pump sumps can lead to reduced pump efficiency, rough running and overloading of a motor drive, all due to the creation of air-entraining vortices as a consequence —it is a very simple conclusion—of asymmetrical approach of the water to the suction inlet. How astonishing it seems that such a problem should not have been examined long, long ago! The laboratory has in hand, besides these and other examples of work of more immediate practical importance, a number of researches of a more fundamental nature. Naturally, since pump manufacturers are well-represented amongst the firms supporting the Association, the study of flow and energy distribution within centrifugal pumps figures amongst them. So, too, does the study of seals and gland packings. The Association is also interested in various civil engineering hydraulic problems like the flow of water over spillway weirs and down spillway channels and has, within its short life, succeeded in solving a number of problems relating to particular structures.

A number of research establishments have held Open Days over the past few summer months and we have had the chance to see much of the work going forward. It is here in the research field that the plaint is often made that specialisation is going so far that workers in one field are incapable of understanding what is going on in another. It is a plaint that seems to us only partially justifiable. In pure science it is undoubtedly true that the jargon of one specialist may be incomprehensible to another. We doubt, for example, whether a physicist is any less completely floored by many of the letters on, for example, biology, that are printed in our contemporary, *Nature*, than is an engineer. It is also true that much of the language of metallurgy is incomprehensible to engineers; and even partially true that a mechanical engineer may find much in electrical engineering difficult indeed to understand. It is even true that specialists in, for example, control gear, talk a language so full of jargon that the non-specialist mechanical engineer needs a glossary to follow their discussions. But though pessimists may be right in assuming that a centripetal influence acts over the whole field of science tending towards a fragmentation so that physicists, chemists, biologists, botanists, geologists, and all the rest, become increasingly incapable of understanding or appreciating what is going on in any field other than their own, there is a factor within engineering that prevents such fragmentation ever proceeding too far. The purpose of research and discovery within the engineering field is to improve the practice of engineering. Sooner or later, therefore, the most abstruse and fundamental of researches must come to earth. An engineering research serves no purpose if its results can be expressed only in terms so obscure and a jargon so incomprehensible that only specialists in its field can understand it. If it is to serve a purpose it must be so interpreted that a designer or a user of plant can utilise its results. This does not mean that every engineering designer and draughtsman and every user of engineering plant must be able fully to understand

what every research worker is doing. It does mean, however, that what is discovered by research must be translated, either by research workers themselves or by others, into terms that will give, at least, qualitative understanding to designers and users.

Often when a research establishment is visited the unspecialised visitor will find that to enquire what is the practical import of any investigation will throw light upon what is going on. For example, in studying the flow of oil through small orifices at high pressure the hydromechanics laboratory has found that at a certain, apparently critical, rate of flow the issuing stream breaks away from the walls of the orifice with a consequent sharp change in the coefficient of discharge. Obviously, the critical region is one that a practical designer should seek to avoid in any mechanism or instrument dependent on fluid flow. But this enquiry into the practical significance of a research cannot suffice even to evoke a qualitative explanation of what is going on when more fundamental investigations are concerned. The long-term purpose of the investigations may well be to formulate a generalised theory, the practical value of which is clear enough. But to be told merely so much is to be told the obvious. What the enquirer wants to know is what differing hypotheses there are, what support there is for them, what difficulties there are in accepting them and what is the significance of work being done elsewhere. Here, indeed, owing to the difficulty of expressing to anyone other than a brother specialist and in language only comprehensible to him what is going on, there is a real risk of fragmentation of engineering knowledge. It may be, indeed, that a new class of men may be needed who can interpret to others what progress is being made in various fields. For fragmentation might prove disastrous to further advance. As Sir George Thomson points out in his recently published book, *The Foreseeable Future*, many advances in science and technology " come from applying ideas or techniques in fields other than those for which they were originally intended." If one specialist is incapable of appreciating the work of another in a different field an essential clue may be missed. Sir George, in fact, foresees that " semi-popularisation will have to be greatly extended " and that " those who do it successfully deserve quite as high a place in scientific esteem as research workers." He may well prove to be right. For it is notable already what a high value is placed upon lectures of the kind that survey the present situation in specialised fields, bringing into a relationship comprehensible to any technically trained man the work of numerous researchers attacking abstruse problems from differing angles. The Hatfield Memorial Lecture to be delivered by Dr. Edgar C. Bain of the United States Steel Corporation next Monday at Sheffield promises to be a particularly fine example of a lecture of that character.

" A WAVE AT THE BOW "

Since the publication of the British Railways Modernisation Plan, in January last, so much has been said, and written, by commentators, official and otherwise, friendly and critical, that one would feel there is little more to be added until the scheme gets fairly into its stride and we can begin to judge by results. But on Thursday, October 6th, Mr. J. C. L. Train, a member of the British Transport Commission, in addressing the Western Region London Lecture and Debating Society at Paddington, touched upon some of the human aspects of the plan in addition to mentioning certain major technical questions that the Commission had under immediate consideration. He began by quoting the old Scots fisherman's expression : " If there is not a wave at the bow there is something far wrong." Applying it to railways as well, he emphasised that the industry cannot afford to stand still. It is not merely a question of providing new equipment. Mr. Train, with ample justification, said he could not imagine an industry in which the equipment was out of date, or dilapidated, where the morale of the workers does not suffer in consequence. But at the same time the whole basis of the modernisation plan is good human relations. " In other words," he continued, " we may provide all the modern equipment known in the world, but unless we get the co-operation of the staff in making use of it we will simply have spent a vast sum of money without getting an adequate return on it." That, to our way of thinking, is taking a very placid view of what might easily develop into a catastrophic position. To-day there are increasing signs of deterioration in many parts of British Railways ; the working out of the modernisation plan inevitably takes time, but when eventually the new motive power becomes available " the wave at the bow " may no longer be that of a tall ship sailing purposefully on her course, but that of a fugitive flying headlong and out of control before a storm.

As Mr. Train said in his address, motive power is the key to the plan. It is in this respect that the present tendencies appear to be so disquieting. From reports reaching us from many parts of the country there seems little doubt that the past summer has been an exceptionally difficult one from the viewpoint of engine troubles. One could take the view that this is merely symptomatic of the steam locomotive being " on its way out " ; that individual units are out-of-date, dilapidated and unequal to the tasks set to them. But as Mr. K. J. Cook said in his presidential address to the Institution of Locomotive Engineers, the standard of repair in the major locomotive workshops has never been higher, and we know from the nature of some failures that they are quite unconnected with the design or age of the locomotives concerned. It is in the running sheds that the major evils seem to be growing. Whether it is shortage of manpower, indifference, or slovenly work we would not like to say. We would agree with Mr. Train that the younger men in particular need something new to stir their imagination ; but they need it now, not in two or three years time when the new motive power comes upon the scene. How such stimulus can be provided is indeed a problem when the time of so many executives is concerned with long-term planning for the future. But we feel that human relations during the transition years are as vital, if not more, than in the final execution of the plan.

In his references to the plans for eliminating steam on the lines west of Exeter, Mr. Train mentioned that an initial order for eleven diesel-hydraulic locomotives should provide the data on which the conversion scheme could be carried out. But here again the time factor is apparent. The new diesels, with hydraulic transmission, will, by the very nature of things, be experimental in themselves, and we can foresee the passing of several years before the new power is established on a solid footing. Again, with the ultimate conversion to full electrification the Commission seems favourably disposed towards the use of alternating current at 50 cycles. While this would enable considerable savings in cost of electrical equipment to be made, it would, with the greater clearances from earthed structures required by the high-voltage conductor wires, be necessary to undertake a great deal of work in the reconstruction of bridges, tunnels, and other structures to provide the necessary clearance, unless, as Mr. Train suggests, special arrangements were made for reduced voltages over short sections of line. From his address, indeed, one gains the general impression that the carrying out of the plan is going to be a much longer job than the original report suggested. He was rather more explicit as to the future standards of speed, and while the original report referred to 100 m.p.h. trains, the target for the future quoted by Mr. Train himself was one of start-to-stop average speeds of about 75 m.p.h., involving maximum speeds of 100 m.p.h. or slightly over. Perhaps we have unduly laboured the difficulties of the transitional stages of the plan, and indeed of the period of waiting before the plan begins to get going at all ; but we applaud Mr. Train's optimistic conclusion, and with him look forward to the time when " the country will have to agree that railways are a virile and not a decaying industry—that they are 130 years young, and good for as long again."

A Seven Day Journal

Opening of New Laboratory

LAST Tuesday, October 11th, we had the pleasure of attending the opening ceremony and a lunch on the occasion of the inauguration of new laboratories at Garringtons, Ltd., Bromsgrove. The new laboratories were declared open by Dr. T. Emmerson, director of research, G.K.N. Group Research Laboratories. These laboratories, which contain departments for mechanical testing and chemical analysis on the ground floor and for metallography, photography, pyrometry and experimental heat-treatment upstairs, are relatively small, since they are auxiliary to the central G.K.N. group research laboratories at Wolverhampton. The floor area is 6000 square feet. The main purposes of the laboratory are to test mining materials, to keep a check on operations within the works and to experiment upon certain subjects of interest within the works, such as heat-treatment. At the luncheon which followed the official opening of the laboratories Mr. R. P. Brookes, chairman and managing director, remarked that the firm had been founded in 1832 and that it had expanded in output by thirty-seven times in the last sixteen years ! Dr. Emmerson remarked that the new laboratory will prove helpful to the whole G.K.N. organisation. He also made a plea that all who used the services of a laboratory should go to it asking for the " truth " and not for proof of what they wanted proved ! Technical work, he concluded, was not glamorous. It was over 90 per cent perspiration. But what technical people could do was to have ideas. Many arguments between producers and users could be resolved when a technical situation was properly understood by both sides.

Institution of Structural Engineers

ON Thursday, October 6th, Mr. Stanley Vaughan was installed as president of the Institution of Structural Engineers for the session 1955–56. Following this brief ceremony, Mr. Vaughan delivered his presidential address, which was concerned mainly with the affairs and growth of the Institution. That subject had been prompted, he noted, by the fact that the twenty-first anniversary of the granting of the Institution's Royal Charter fell in 1955. During that twenty-one-year period, Mr. Vaughan explained, the Institution had made steady progress, in membership and in the standard of its examinations. After a somewhat detailed account of these matters he commented on the influence which the Institution had had over the progress of structural engineering during that period. In particular, Mr. Vaughan pointed out that the codes of practice on steel and concrete construction which the Institution had fostered, had been very important is promoting more rational design, and in more recent years the Institution's publications on aluminium and prestressed concrete had given authoritative guidance at an opportune time. The scope of structural engineering had increased enormously over the past twenty-one years, the president noted, and new materials, such as welded steel, prestressed concrete and aluminium, had come into use. Considerable advances in theory had been made, too. But there was one criticism he would have made of the Institution's—and also of other Institutions'—progress. The charter referred to the advancement of " the art and science of structural engineering," and although the " science " had advanced he doubted about the " art." Mr. Vaughan used the latter term to refer to the æsthetic aspects of structural design. He thought that a structure designed purely according to mathematical principles would inevitably have a pleasing appearance. But other factors, such as fabrication techniques and the use of standard sections, complicated that simple idea. He thought therefore that structural engineers and architects should have a thorough understanding of each other's aims ; furthermore, he remarked, a structural engineer's education should be as wide as possible, particularly in the study of buildings of all kinds, so that he would have an opportunity to develop good taste in these matters. The new president is a partner in the firm of Oscar Faber and Partners, and he succeeds Mr. S. B. Hamilton as president.

Opening of a Terramycin Plant

ON September 30th a plant for the manufacture of Terramycin was officially opened by Lord Brabazon. The plant, which has been built by Pfizer, Ltd., represents a large investment of American capital and will supply all the needs of the sterling area for this American antibiotic drug, which has been developed out of research into innumerable soil samples collected from all over the world. Lord Brabazon, who was introduced by John J. Powers, the senior vice-president of the American company, referred to the historical importance of Sandwich and to his admiration of research scientists, among whom he included Sir Alexander Fleming. He contrasted the beneficial uses of the new drug with the destructive uses to which other advances in technology have been applied, and as part of the opening ceremony dug a sample of soil from the factory site to add to other soil samples gathered from different parts of England for transmission to America. Mr. J. A. Rogers, director and general manager, said that he had heard the new plant described as an act of international medical brotherhood, and said that what it would achieve would help to raise the standard of living in many communities. This project, he went on, meant a considerable saving of dollar expenditure and also that this antibiotic would now be available in the sterling area as a British export. Terramycin, he continued, was in increasing demand not only from the medical profession, but from veterinary surgeons and farmers. As an example of the value of the drug to agriculture Mr. Rogers mentioned its use as a supplement to feeding stuffs, resulting in a reduction in the amount required and the freeing of thousands of acres for the growing of other crops.

British Transport in the National Economy

LAST Monday evening, Mr. Peter Masefield delivered his presidential address to the Institute of Transport, his subject being " British Transport in the National Economy and an Appreciation of its Major Components." At the outset of his address, Mr. Masefield made a plea for the proper use of the old English word " transport " in our affairs, and " the eschewing of that unwieldly Americanism ' transportation ' ! " The full objectives of transport, he continued, could be achieved only by offering convenient, sufficient and punctual services, at appropriate speeds and standards of comfort. Those services must be operated with safety, economy, reliability, regularity and frequency, in adequate vehicles, with well-maintained amenities, at economic fares attractive to the public. Mr. Masefield then proceeded to a comprehensive review of the " five major components of British transport " which he enumerated as shipping, railways, roads, air and inland waterways, and to a detailed survey of the transport industry. He rounded it off by saying that we could look forward to a wide field of development ; at sea, towards lower costs at somewhat higher speeds ; on rails, towards much lower costs and with some speeding up of schedules where track congestion was not too great ; on roads, towards a freeing of bottlenecks and a system designed for motor transport rather than the stage coach, and in the air, towards the most spectacular development of all which was higher speeds with lower costs. Technically, Mr. Masefield asserted, we were undoubtedly on the threshold of altogether new power plant developments which would be as much in advance of to-day's power units as we were to-day ahead of " The Rocket." The two major problems of the transport industry were, he added, first, adequate expenditure on development, on capital outlay and on fleet replacements, and, secondly, the organisation, control and administration of the operating units. If we were to go forward in this most important of the nation's industries, Mr. Masefield said, money must be found for its economic development, and efficient operating units, of suitable size and flexibility for the job in hand, must be built up. It must not be forgotten that transport as a business was still expanding fast.

Vehicle Inspections at Slough

THE vehicle inspection centre, operated at Slough for one month beginning June 27th last, examined 1810 vehicles, predominantly cars, with 128 motor-cycles. Of the cars, one-quarter were less than two years old and three-quarters were of post-war construction ; the technical significance of the results of inspections is slight, because no indication appears of the origin, history or design of the vehicles. However, a striking finding is that in this spectrum of cars 47 per cent had steering defects, worn king-pins being most prominent. Bad aiming of headlights was widespread, around 35 per cent being outside a band of main beam 0 deg. to 1½ deg. below horizontal. Brake lights were defective on 17·4 per cent and tail lights on 6·2 per cent ; turning indicators were defective on 15·7 per cent of cars and light vans. Braking performance was measured by an accelerometer in a road test, or by a roller type brake testing machine measuring each brake individually, the sum of the braking efforts divided by the vehicle weight being taken as the brake performance. The two methods did not yield directly comparable results ; only 44 per cent of cars had brake forces less than 80 per cent of the vehicle weight, but 62 per cent of those road tested did not achieve a deceleration of 0·8g. Sixty per cent of the motor-cycles had brake performances of 80 per cent on the front brake, and rear brakes reached this standard on 30 per cent ; the relatively light loading of front wheels in uniform motion explains this contrast. Forty per cent of the cars had one, two (almost as often) or more tyres in bad condition, front wheels apparently offending most : two poor front tyres occurred as often as one poor rear.

Electrical Engineering Prospects

By SIR GEORGE H. NELSON, Bt., M.I.Mech.E., President, I.E.E.*

In his inaugural address as president of the Institution of Electrical Engineers, delivered in London on October 6th, Sir George Nelson discussed the great prospects and the responsibilities of electrical engineers in contributing to the benefit of mankind. Sir George's theme ranged over the past, present and future of electrical engineering. Extensive abstracts from his address are reproduced here.

I WILL start the picture of the past with our first president, Charles William Siemens, who, it is interesting to recall, founded a section of my own company. I had the pleasure, some two years ago, of presenting to the Institution facsimiles of his letters, giving fascinating pictures of the technical and social life of his time. From this correspondence letter No. 43 shows that, as long ago as 1873 Parliament had moved for the appointment of a committee " to inquire into the causes of present dearness and scarcity of coal " !

His address to the first meeting of our Institution—then called the Society of Telegraph Engineers—in February, 1872 (the Society having actually been founded in 1871), was most prophetic. He pointed out that what to many then seemed to be separate compartments of science and engineering, were really one, involving a vast range of problems in theoretical physics, applied chemistry, engineering and industrial management, developing into the whole field of electrical engineering as we know it to-day. He said :

" There is hardly a problem in electrical science that is not of practical interest to the telegraph engineer . . . The phenomena of electrification and polarisation, of specific induction and conduction, the laws regulating the electrical wave, the influences of . . . temperature on conduction . . . the potential force residing in a coil of wire of a given form, when traversed by a current, involve questions belonging just as much to pure physical science as to the daily practice of the telegraph engineer . . ."

and went on to refer to :

" . . . questions of selection of materials for conduction or insulation . . . and apparatus for producing and directing . . . electrical current which . . . call into play considerations . . . of purely mechanical import. . . . I would go further and include statistical information."

He concluded :

" These remarks may suffice to show how great is the field of our activity and how much remains to be accomplished notwithstanding the extraordinary progress of which we are apt to boast."

After this address Mr. C. F. Varley, F.R.S., made most interesting observations, as follows :—

" Mr. President . . .

" After your address, Sir, no one will fail to see . . . this Society . . . will gradually, by natural selection develop more into an electrical society . . . the moment it is understood that all papers on electricity, or bearing directly upon the development of electrical science are admitted . . . because it will be found ultimately to embrace every operation in nature."

Our Institution, starting in this atmosphere of the widening orbit of electrical science and engineering, was to see its original name changed twice in less than eight years, first to " The Society of Telegraph Engineers and Electricians," in 1880, and then to the " Institution of Electrical Engineers," in 1888, when the professional term and title of Electrical Engineer was established.

The work of the Institution and our profession had progressed so much by 1921 that a Royal Charter was applied for, and was granted—a very fitting honour and recognition of the Institution's central role in establishing high professional standards and propagating and encouraging the science and technology of electricity, which has brought such a revolution in the lives of people everywhere.

Our predecessors have striven from the very beginning for the establishment of standards at the highest level, and we and our successors will, I am sure, jealously guard and uphold them.

To refresh your memories on the progress that has been made in the generation, distribution and use of electrical energy, I would mention that in 1905 many generating plants were of the order of only a few hundred kilowatts, powered by reciprocating prime movers, and that the total generating capacity in Great Britain was 1700MW, being only $^1/_{20}$kW per head of population. At the same time in the United States the total generating capacity was 6800MW—only a little over $^1/_{12}$kW per head of population.

What immense advances over these figures are shown by to-day's statistics, for by June of this year the total generating capacity in Great Britain had reached 25,500MW, or $\frac{1}{2}$kW per head of population—a tenfold increase.

The capacities of individual generating sets have risen in fifty years from a few hundred kilowatts to over 100MW and, quite recently, sets of 200MW have been ordered.

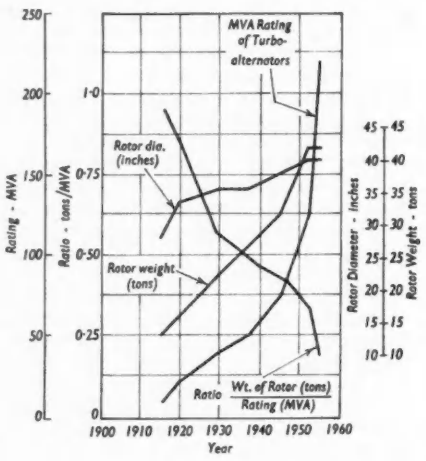
In the United States the installed capacity, in the same time, has risen to over 121,000MW, or $\frac{3}{4}$kW per head of population, and this includes sets larger than 200MW.

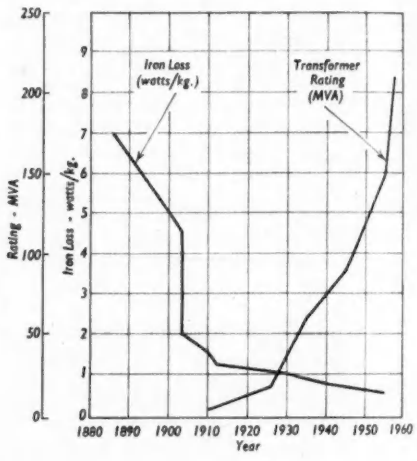
These developments have brought about a steady fall in the cost of electric power in comparison with the cost of living over the past thirty years, amounting to more than 45 per cent in this country and 50 per cent in the United States. The advances in the design of electrical equipment have come from great imagination, courage and enormous expenditure on research and development by the heavy electrical manufacturing industry financed almost entirely from its own resources.

Fig. 1 indicates some of the technical changes that have taken place in turbo-alternators in the past forty years. It will be seen that although the output of machines has increased more than twenty times, the rotor weight has gone down from nearly 1·0 ton/MVA to 0·2 ton/MVA, i.e. it has been reduced by 80 per cent. Both these changes have been made possible by new techniques—including the introduction of hydrogen cooling—arising from research. Similar changes have taken place with the steam turbine, through the use of higher steam pressures and temperatures.

In distribution, similar spectacular advances have been made. Fig. 2 indicates some of the changes in the design of transformers. The curve shows what a big advance took place about 1905 with the introduction of silicon steel—invented by Hadfield. More improvement is now obtained through grain orientation during the manufacture of the silicon iron. The result has been that the power losses per pound of core iron have been reduced to one-quarter of what they were fifty years ago, and ratings have gone up from 5MVA to more than 200MVA, with a rise in transmission voltages from about 6kV to 400kV.

As a result of continuous and intensive research and development, corresponding progress has been made with switchgear for dealing with equally spectacular increases in transmission voltages from 6kV up to 400kV. Similarly, interruption ratings have risen from 25MVA to 10,000MVA.


MVA Rating of Turbo-alternators
Rotor dia. (inches)
Rotor weight (tons)
Ratio Wt. of Rotor (tons) / Rating (MVA)
Rating - MVA
Ratio - tons/MVA
Rotor Diameter - inches
Rotor Weight - tons
Year
1900 1910 1920 1930 1940 1950 1960



Figs. 1 and 2—Development of turbo-alternators, and (right) transformers

In the telecommunication field progress has been staggering. Fifty years ago few homes had a telephone, Marconi's monumental achievement in transatlantic radiocommunication was only four years old and there was no system of radiocommunication as we know it to-day. The first patent for wireless was only taken out in 1896, and a British company, formed the following year, was the first to bring wireless telegraphy to the world.

The first public broadcast of news and entertainment did not come until 1920, and the first television service until 1936. Colour television could come at any time now, when the economic position allows it, since the technical problems are mainly solved.

Progress in the application of electrical and electronic control to many important industries is increasing production in a spectacular manner, and also improving quality. An outstanding example is the rolling of sheet steel which, up to thirty years ago, was produced from steam-driven mills in small sheets at a rate of about 2·5 m.p.h. To-day, sheet steel of much more accurate

* Chairman of the English Electric group of companies

dimensions is produced in coil lengths of 15 miles, leaving the rolls at a rate of nearly 60 m.p.h. The control of liquid and gas flow and the control of temperatures in the delicate processes of oil refining is another field of important application. What further advance in productivity in other industries will result from a combination of electric power and electronic methods of process and machine control one can only guess, but the fields for such application are unlimited.

Next comes the gain in users' time and in efficiency, by the use of the electronic computing machine, in the solution of research and design problems. These machines are already saving man-weeks and man-months of engineers' and mathematicians' time, solving problems in research and design in electrical, aerodynamic and many other branches of science and engineering. In fact, the availability of these machines has enabled problems to be solved which, up to the present, had not been found possible, owing to the effort needed for their solution.

Future Prospects

With these brief comments on the achievements of the past and present, I will now turn to the prospects of the future together with the problems that will be associated with that progress.

From my extensive travels oversea, and from discussions with those carrying the highest responsibility in the many countries visited, particularly since the end of the 1939–45 war, I have found an almost unanimous determination—not just a hope—I repeat, a determination, of all nations—whatever their race, creed or state of development—to improve their standard of living, and they all realise that the key to this lies in the greater application of electric power to the source of their national economy, including agriculture, communications and industry. In other words, economically, they all have an expansionist policy.

To the electrical engineering profession and industry this brings increased responsibility now, with a steadily increasing demand for engineers and for electrical equipment by the pressure of more and more people everywhere, as the population of the world increases.

Let us briefly review the prospects of the growth of the world population. Estimates given by Palmer Putnam in his book,† and also statistics issued by the United Nations, show that the population of the world has risen from 1100 million in 1850 to 2400 million in 1950. Over half of that population are living in areas where there is an immediate and continuing pressure for improvement in economic standards. It is estimated that by the year 2050 the world's population will have increased to 2½ times the 1950 figure, reaching the gigantic total of 6000 million.

These estimates of world population cannot, of course, be taken too factually, because of the difficulty of obtaining reliable censuses in the under-developed countries; they can be nothing more than rough estimates, but they suffice to indicate that both living standards and world population, steadily and substantially rising, will increase the demand for more and more electric power.

At the recent Geneva Atomic Energy Conference, Professor Robinson and Dr. Daniel said that by the year 2000 the world consumption of energy would be not less than the equivalent energy of 7500 million tons of coal a year, representing a threefold increase in total energy consumption in the next fifty years.

These prospects compel us to recognise the needs and compel us to solve the problems which will arise from the steady exhaustion of conventional fuels and basic materials which will be used in meeting the needs of the increased population and the higher standards of living which they will expect.

Fortunately, under the pressure of the need to defend our way of life, we carried on great research and development in the field of nuclear physics through which—by Providence — scientists, technologists and engineers are finding a solution to the exhaustion of conventional fuel in the development of the basis of the means of generation of electric power from nuclear energy.

I had intended to make considerable reference to the bright future in this field, but so much has been said and written, since I framed this Address, that I feel you are all reasonably up to date with the position, and I will simply say, therefore, that the progress made in this field of nuclear energy forms one of those miracles which occur from time to time, at the appropriate moment, to meet the needs of mankind.

Need for New Materials

The solution of the fuel problem in the generation of electricity is therefore undoubtedly in sight, but we must not for one moment think that this is the only problem with which we are faced in meeting the needs of improving the standards of living of the world and of a growing population. However, just as research and development in nuclear physics provide an alternative source of heat for generating steam, so equal and intensive study, research and development in fundamental physics will provide alternative sources of supply of other basic materials, and this must be followed up immediately.

The measure of urgency arises from the fact that 90 per cent of the present population of the world has a standard of living below that in the United States and Great Britain, and it has been estimated that if the standard of this 90 per cent were raised overnight to that of Great Britain, the resources of basic materials like iron and copper, &c., would be exhausted in twenty-five years. Progress, thank goodness, cannot take place at this rate, but it does indicate that the rate of exhaustion may easily become an acute problem in 100 years. One hundred years is a very short period, in normal times, in which to solve problems of such immense and fundamental character as producing appropriate artificial substitutes, and/or producing synthetically basic metals in quantities as the result of recent research into transmutation or synthesis of a heavy element from a lighter one.

Prominent in the field of production of artificial substitutes are the cellulose products. The possibilities in this direction can be measured by realising that the energy which reaches the earth from the sun every day is estimated to be at least 50,000 times the total energy produced from all man-made engines in the world to-day—i.e., electrical generating plant, motor-cars, ships, &c.—and it is this solar energy which provides the base of cellulose pulp.

In visualising the possibilities of artificial fibres, I would mention that Terylene fibres have physical properties comparable with steel, which indicates that in time means may be found of economically producing materials in suitable forms as a substitute for steel for structural purposes, making it possible to conserve the use of iron ore to make steel for its magnetic or other special properties.

Similarly, a synthetic material has been produced from which is now manufactured, among other things, pipes, for conveying hot, cold or corrosive fluids. This is replacing copper or lead at a fraction of the price and with less liability to corrosion, and so helps to conserve two metals whose supply is rapidly diminishing.

What immense possibilities towards meeting the needs of the future this picture presents, and how important it is that it should also have immediate intensive study and attention.

Although it has no bearing on the value of solar energy which reaches the earth to-day, I cannot conclude my reference to energy from the sun without reminding you that normal fuels, such as coal and oil, used to-day for power generation, received their stored energy from the sun, and, of course, the falls of water generating hydro-electric power spring from water originally evaporated by the sun's energy making use of the earth's contours.

I feel that the Council and the members of the Institution are to be congratulated on their vision in agreeing that the Institution should play its part in forming and becoming a founder of the British Nuclear Energy Conference in association with the Institutions of Civil, Mechanical and Chemical Engineers and the Institute of Physics. To make most rapid progress from research and development in the field of nuclear physics it is necessary to embrace the sciences, the technology and the engineering of all these Institutions, and therefore the establishment of this conference is of great national importance.

It cannot be denied that outstanding benefits have come from development initiated or extended to create the means of destruction. It is now possible that the latest discoveries of our scientists and technicians of the hydrogen bomb may make the risks of war so terrible that man will not face the consequences of the possible annihilation of our species.

Even if this is successful, I feel that armies and navies will still not be completely abandoned, for some will be necessary for policing the world to deal with minor situations, but they will be in much smaller measure, and consequently it will be possible to release a considerable number of scientists, technologists and engineers from the study of the means of the destruction of man in order to play their part in the improvement of world conditions. Pride can be taken in the results which have so far sprung from the remarkable co-operation between scientists, industrialists and the Government in wartime. It is heartening to find that our Government is continuing to pursue a similar policy in peacetime in the field of nuclear physics, the research and development of which are enormously costly and which could not possibly be borne by individual firms.

Recruitment of Electrical Engineers

I must issue a warning that the release of scientists and technologists from activity on war equipment will not be sufficient to solve all the problems to which I have referred in my Address, and the Institution therefore must continue to play its part in pressing for still greater facilities, and to continue to advise on the methods of education and training of electro-technical scientists and technologists, in order to overcome the shortage of technical manpower, not only in this country but also in the Commonwealth.

The Institution is to be congratulated on

† *Energy in the Future.*

the steps it has taken with industry in producing its film entitled "The Enquiring Mind," with the object of attracting the interest of parents and boys in science and technology, thus stimulating recruitment in these fields. I sincerely hope it will be successful in convincing both parents and boys that the study of science and engineering can be just as powerful in forming well-rounded human minds and will develop at least as good character as the traditional subjects which we know as the humanities, and are professions of high standing providing stable employment and great scope. It is particularly necessary to attract a great proportion of the young people who still choose to pursue the Arts at various levels, in spite of the need for technologists for the improvement of the world. Another possible source of supply would be by influencing young men who are potentially good, but who take no further steps to carry their education to the graduate standard.

Further interest, I feel, could be stimulated by increasing substantially, with necessary supporting facilities, the numbers of well qualified teachers in mathematics and science subjects in secondary schools; also by arranging that effective steps are organised continuously and clearly, explaining to boys who have reached the General Certificate of Education level the opportunities of a career in scientific rather than non-scientific subjects, so influencing the transfer of promising boys from one side to the other.

Parents' interest could be stimulated by readjustment upwards of the facilities for awarding scholarships, particularly to help parents who have several children to educate. It is important that technical colleges not affected by the Minister's recent announcement of the upgrading of certain technical colleges to university standard should not be lowered in standards or facilities. In fact, there should be an extension rather than any curtailment. Also, if a student following a part-time course shows great promise during his development, he should be transferred to a sandwich course or full university course.

But I would emphasise that there is great scope for careers masters at schools who have that rare gift of being able to assess a boy's potential development, and they must be given the facility to push forward boys of special ability and to encourage their enthusiasm for their work.

As an industrialist who makes a substantial demand on the supply of technical personnel, and who, to help the position generally, has set up very great resources for practical and advanced specialised training of appropriate young men, I have supported wholeheartedly the policy worked out by the Council's expert committees, for I believe they have interpreted correctly the present needs of the whole industry and foreseen properly the future technical demands that will be made on the men concerned some years after their graduation.

I would say that I support very strongly the warning issued by the Barlow and Percy Committees—that on no account must the demand for quantity be allowed to lower the standards of quality. I would say that remarks have been made to me, both at home and abroad, which implied that some people think that the Institution is raising its educational requirements above what is necessary, implying also that it was limiting recruitment to the profession. I vehemently denied this and pointed out that nothing was further from the truth for, on the contrary, the Institution, while supporting the policy of increased quantity with quality, was pursuing an energetic campaign to attract a larger share of the output of boys from secondary schools to take engineering courses and so increase the input to the technological field and, if of appropriate qualifications, to membership of the Institution.

A very important phase of the supply of technical personnel is the special, great and urgent need for technically qualified men who have the natural gifts for management and highest administration. The ideal men for such appointments undoubtedly are those who are qualified in science and technology and who, in addition, have the inborn qualities of character, powers for leadership and that rarest of all senses—common sense—the combination of which earns the respect and confidence of others.

Such qualities are born in men and are not made by education. The greatest problem is to catch the person as soon as these characteristics appear, and to develop his natural gifts in association with scientific and technical education. I am sorry to say I cannot write a specification for somebody to use for the selection of such men. I can only suggest that the supply could be increased by appointing as school careers masters men who have the gift of spotting them, and who can ensure that they receive appropriate training.

I suggest that the careers masters at schools and colleges with the gift for recognising those with management qualities can do much to help in this work. The adequate supply of future managers is fundamental, because the best results from design, manufacture and operation can come only with efficient management intimately familiar with the widest aspects of the business concerned.

Great Britain has very few natural resources and without doubt its scientific, technological and skilled people are its greatest economic asset. This being so, they must be employed in the most efficient manner and their use on duplication or further multiplication of effort on the same problems should be avoided, in the interests of the nation and the Commonwealth.

I feel that, great as the Address of the first president, in 1872, was, at that time there were no fears about the imminent exhaustion of supplies of basic materials. Neither did this question seriously arise as recently as fifty years ago, but to-day the effect of increasing demand and growing population on the world resources of materials has inspired the theme of my Address.

This is not a vague question for the future, but it is with us to-day. If a lowering of the standard of living through the exhaustion of natural resources is to be avoided, immediate action to produce synthetic substitutes of all kinds must be taken now. Electrical engineers will have to play a prominent part in these developments, which, in turn, will bring increased responsibilities to the Institution for ensuring that adequate numbers of qualified electro-technical scientists, technologists and industrial administrators are available for this vital work—responsibilities which will undoubtedly be met.

Thermal Flowmeters for Small Flows and High Pressures

By H. R. RONNEBECK, M.Sc.

The capillary pressure-drop flowmeter has hitherto been the only high pressure meter available for rates of flow below those suitable for rotameters. It has proved inaccurate because of unknown viscosity changes in the fluids and of unsuspected solid particles deposited in the capillary. Three thermal flowmeters are described which are free from these defects. The calibration of one of them is unaffected by pulsating flow.

HIGH pressure capillary flowmeters hitherto used for flows at rates below those suitable for rotameters have proved unreliable because of the large effects of unsuspected particles of dirt in the capillary and of viscosity changes. The unstable region between streamline and turbulent flow can also be troublesome. This resulted in a request for more accurate 250 atm flowmeters to cover the ranges 0–0·5 litre per hour of liquid and 0–1·5 cubic metres per hour of gas (expressed at N.T.P.).

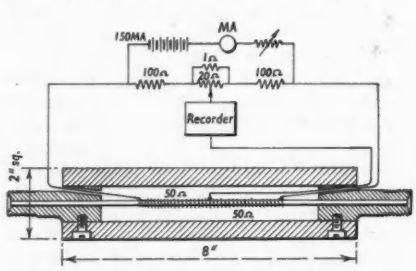


Fig. 1—Thermal flowmeter, Mark I

Historical and General

Flowmeters based on measurement of the heat input required to raise the temperature of the fluid by a known amount have long been known, e.g. the Thomas gas meter for the accurate measurement of very large flows at low pressures. The use of heat instead of pressure-drop has the advantage that mass flow is measured instead of volume flow. The Thomas meter is, however, entirely unsuitable for high pressures because of the mass of metal in the tube and the presence of fine heater and resistance thermometer wires in the gas stream.

In 1945 a thermal capillary flowmeter was developed for liquid flows up to 100 millilitres per hour at 250 atm. It consisted of two similar coils of steel capillary tubing electrically connected in a Wheatstone bridge circuit and heated by a constant current of 3·4A. The coils were enclosed in separate closed air vessels which were immersed in a water bath. The liquid flowed through only

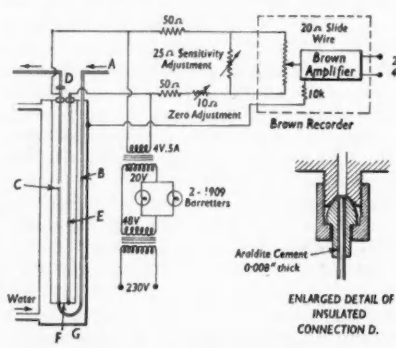


Fig. 2—Diagram of thermal flowmeter, Mark II

one coil and its fall in resistance due to cooling was used to record the rate of flow. Although successful in the laboratory, it was discarded because the special insulating 250 atm lens ring would not stand tightening like a steel one and flow rates in excess of the designed rate were subsequently demanded of it.

In 1947 A. F. Brown and H. Kronberger described a thermal capillary flowmeter in which the capillary was heated by platinum windings.[1] This type of meter appeared to be promising and an instrument suitable for use at 350 atm (see Fig. 1) was, therefore, constructed and calibrated. It would only measure, however, up to 4·5 millilitres per hour of water or 14 litres per hour of nitrogen (expressed at N.T.P.). Its accuracy was not investigated. To overcome this limitation, Brown and Kronberger used their flowmeter with a shunt to measure larger flows at Harwell,[3] but this was for low pressures and both the flowmeter and its shunt were designed for streamline flow. Moreover, the gas was very clean, so that pressure-drop changes due to dirt particles could not occur.

Fig. 3—350 atm thermal flowmeter, Mark II, without covers

A streamline flow shunt suitable for 250–350 atm would be so cumbersome as to be completely impracticable, especially as both shunt and flowmeter would require "thermostatted" water jackets to ensure that the flow ratio between them remained consistent. The use of a shunt has not, therefore, been further pursued.

As it was obvious that reasonably fine platinum windings could not carry sufficient heating current to cater for much larger flows in the Brown and Kronberger instrument, the 1945 design already referred to was reconsidered. It had advantages over the pressure-drop instrument in that unsuspected dirt particles in the capillary did not produce errors; nor was it affected by pulsating flow, by changes in viscosity, or by the unstable region between streamline and turbulent flow. On the other hand, this instrument cannot be used for electrically conducting fluids because they would short circuit the insulating high pressure connection required for the electrical heating current in the capillary. Also, the maximum flow is limited by the pressure-drop through the capillary (particularly for gases below 5 atm) and by the heating current required if larger tubes are used. Tests with straight instead of coiled capillaries were promising and a prototype (known as the 350 atm thermal flowmeter Mark II) suitable for factory use was made. It has been found satisfactory for measuring liquid propylene at 250 atm on a semi-technical plant. The maximum flow was, however, still much less than that originally called for. Increasing the flow reduced the sensitivity almost to zero, while increasing the steady heating current overheated the capillaries when the flow was small. Some improvement was obtained by placing the capillaries in an atmosphere of hydrogen, thus increasing the heat loss and enabling the heating current to be increased, but the maximum flow was still insufficient, while the added complication was not justified.

The required range was subsequently attained by a thermal capillary flowmeter (Mark III) in which the heating current was automatically controlled so that the temperature rise of the fluid was constant. It was later found that by using a larger flowmeter tube and a heating current of 50A, the range could be extended up to 3 litres per hour of water.

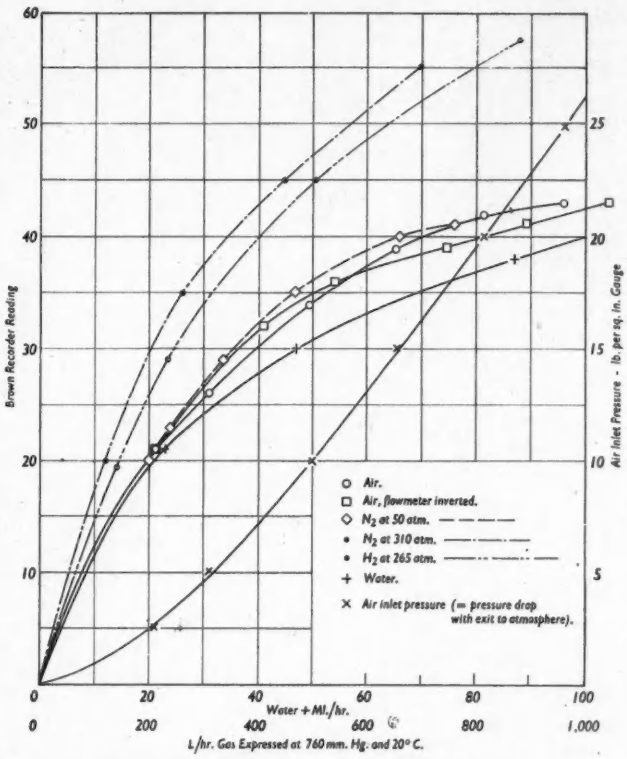

Brown Recorder Reading
Air Inlet Pressure - lb. per sq. in. Gauge
Water + Ml./hr.
L/hr. Gas Expressed at 760 mm. Hg. and 20° C.
Air.
Air, flowmeter inverted.
N2 at 50 atm.
N2 at 310 atm.
H2 at 265 atm.
Water.
Air inlet pressure (= pressure drop with exit to atmosphere).

Fig. 4—Calibrations of Mark II thermal flowmeter on gas and water

350 Atm Thermal Flowmeter Mark II

Description.—Figs. 2 and 3 show the instrument in diagrammatic and actual form respectively. A Brown recorder may be substituted for the Cambridge thread recorder if preferred. Referring to Fig. 2, the fluid passes from the inlet connection *A* through the austenitic steel capillary *B* (1·8mm o.d., 1·2mm i.d.) immersed in the water jacket to bring it to the jacket temperature. It then flows through the electrically heated capillary *C* via the insulating high pressure connection *D* (shown full size in the inset of Fig. 2) to the exit connection. The reference capillary tube *E* is exactly similar to *C* and is electrically in series with it. They form two arms of a Wheatstone bridge and are heated by 6A a.c., which is stabilised by the two 1909-type barretters in the transformer circuit. A thread recorder or a Brown Electronik recorder is connected across the bridge. Fluid flowing through *C* cools it and lowers its resistance, thus unbalancing the bridge and deflecting the thread recorder. If a Brown recorder is used, it is connected as in Fig. 2, so that it rebalances the bridge and moves the pen over the chart in so doing. There is a spring arrangement (not shown) at *F* which serves to keep the capillaries taut and out of contact with the jacket wall when they expand due to heating. A rubber diaphragm at *G* forms a bursting disc so that the water will be blown down on to the floor if a capillary should burst.

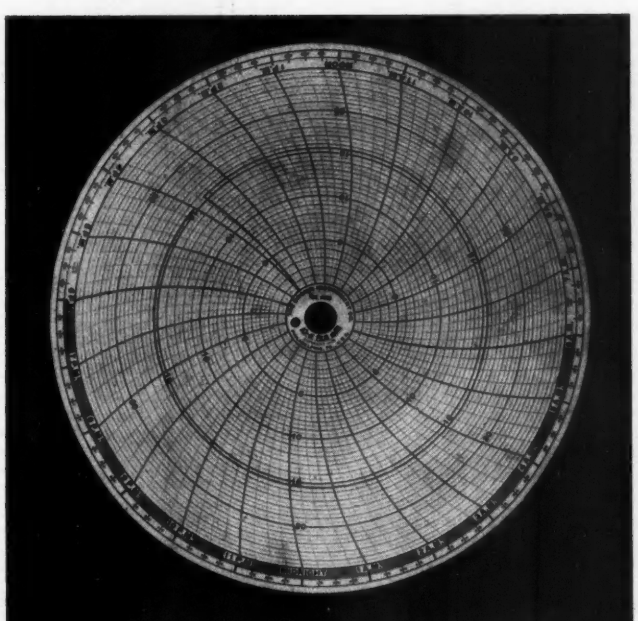


Fig. 5—Twenty-four-hour record at 68 millilitres per hour of water, Mark II thermal flowmeter

This flowmeter cannot be used for electrically conducting fluids because they would short circuit the insulating high pressure connection *D*.

Performance.—Fig. 4 shows Brown recorder calibration curves for gases at various pressures and for distilled water. A pressure-drop curve is also shown. The maximum ranges may be taken as 180 millilitres per

hour of distilled water and 900 litres per hour of gas at 250–350 atm, but at gas pressures of 50 atm and less the sensitivity begins to fall off seriously at 500 litres per hour. It will be seen that raising the gas pressure to 310 atm produces a marked change in the calibration, which corresponds to the increase in specific heat of the gas. At pressures below 10 atm the range is limited by the permissible pressure-drop through the meter (except for hydrogen) and by the cooling effect of the concomitant expansion of the gas. With nitrogen at 50 atm and 250 atm the pressure-drops were too small to be

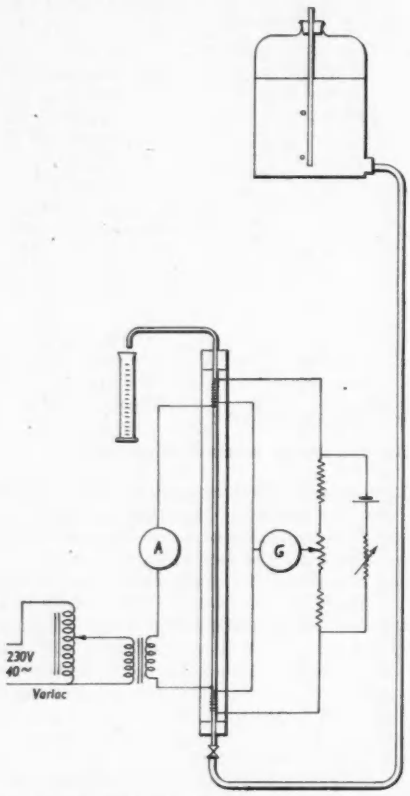


Fig. 6—Experimental flowmeter using constant temperature rise

detected by Bourdon tube gauges. At 20 atm the pressure-drop was ½ atm for a rate of 700 litres per hour. Pressure-drops for air at low pressures are shown in Fig. 4, but it should be noted that, in a similar meter made of a different batch of capillary of the same nominal bore, the pressure-drops were about twice as great. Pressure-drops for a Mark III flowmeter are tabulated for various pressures on page 542. Double these values may be taken as applicable to the Mark II type, which has twice the length of capillary. It may sometimes be convenient to install the meter upside down. The curve for this position shows that there is little change in the calibration. The rate of jacket water flow was immaterial, a mere trickle being sufficient, but reducing the water temperature from 22·5 deg. to 12 deg. Cent. caused the meter to read 6 per cent f.s.d. high throughout its range. This may have been due to a difference in the electrical resistances of the flow and reference capillaries and may vary with different instruments. The effect could be minimised by carefully matching the capillaries. The time lag for full-scale deflection was about four minutes. For 0–¼ f.s.d. it was about 2½ minutes. Fig. 5 shows the record of a 24-hour run on distilled water at a constant rate of 68 millilitres per hour. There is just enough roughness on the actual record to show that the pen had not stuck at its starting value. Repeated runs on

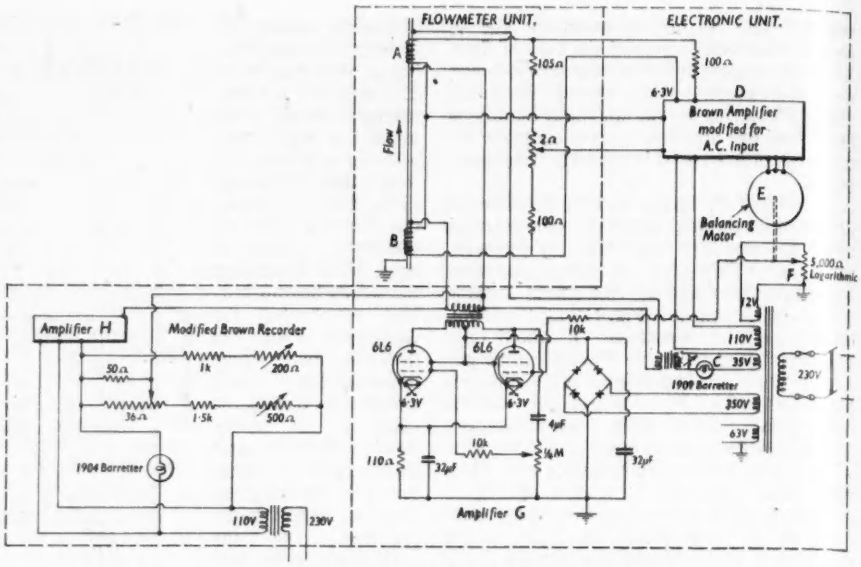


Fig. 7—Circuit diagram of thermal flowmeter, Mark III

distilled water gave readings agreeing within ±2 per cent of the calibration curves.

A second Mark II flowmeter has since been made to cover two ranges (0–10 litres per hour and 0–500 litres per hour of hydrogen at 250 atm) by means of additional resistances and a changeover switch. On the lower range the instrument is working at its highest useful sensitivity and the zero wanders between ±2 per cent f.s.d., with occasional excursions to 3 per cent.

Plant Experience.—The first Mark II flowmeter was used on a semi-technical plant for metering liquid propylene at 250 atm. Its insulating high pressure joint was made with collars of " Fluon " and was pressure tested to 410 atm. The " Fluon " could not be completely trapped in position without bridging the insulation, but the gap between the metal parts was only $^{1}/_{64}$in. When subjected to 250 atm for one week the " Fluon " flowed round two 90 deg. corners and was extruded through the gap sufficiently to cause a leak. The " Araldite " cemented nipple joint shown in Fig. 2 was then evolved and was found to withstand test pressures of 520 atm, provided that the baking technique (described in the Appendix) was correctly carried out. Some trouble occurred at first due to the expansion of the heated capillaries, which allowed them to touch the jacket wall. This was eliminated by fitting the spring tensioning device previously mentioned. At the time of writing the second Mark II flowmeter is only just being put into service.

350 Atm Thermal Flowmeter Mark III

Preliminary Experiments.—Calibrations of the Mark II type having shown that it was impossible to increase its range without overheating the capillaries, it was decided that a constant temperature rise instead of a constant current type of thermal flowmeter should be tried. An experimental meter was made which consisted of a straight 18in length of austenitic steel capillary 1·8mm o.d. 1·2mm i.d. (See Fig. 6). This carried two windings of 44 S.W.G. enamelled nickel wire, cemented 15in apart, to serve as resistance thermometers. Copper wires for the heating

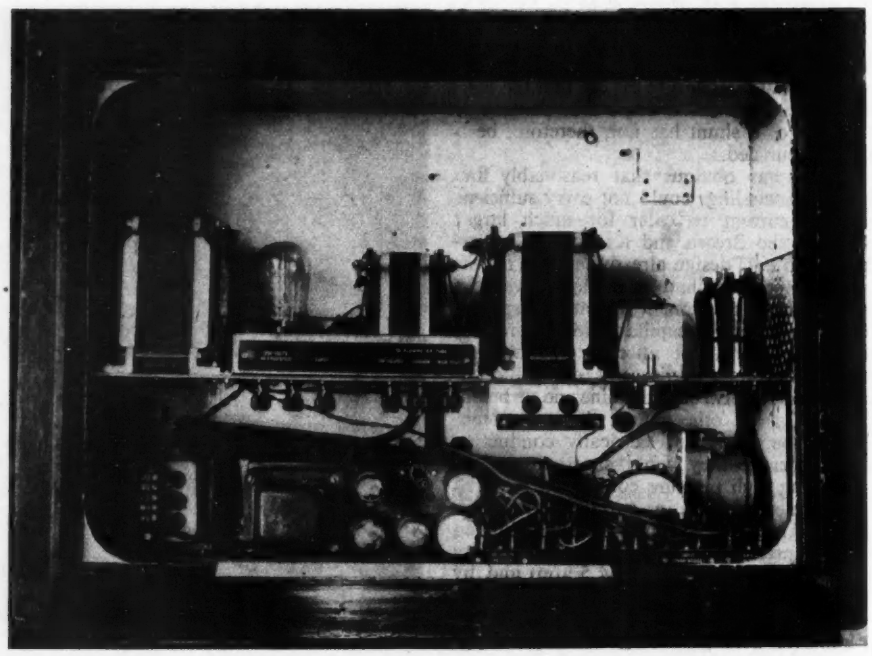


Fig. 8—Prototype electronic apparatus for Mark III thermal flowmeter

current were soldered to the capillary close to the coils. The assembly was enclosed in a 1in bore copper tube and connected as shown in Fig. 6. The nickel coils served as a sensitive differential thermometer and formed part of a Wheatstone bridge circuit, which was set to balance at a calculated temperature difference of 20 deg. Cent.

It was found that the heating current could easily be hand-controlled by the Variac to balance the bridge at rates of flow up to 1·16 litres per hour of distilled water, at which a heating current of 9·6A. was required. The calibration against (current)^2 was linear within ± 1 per cent except near zero

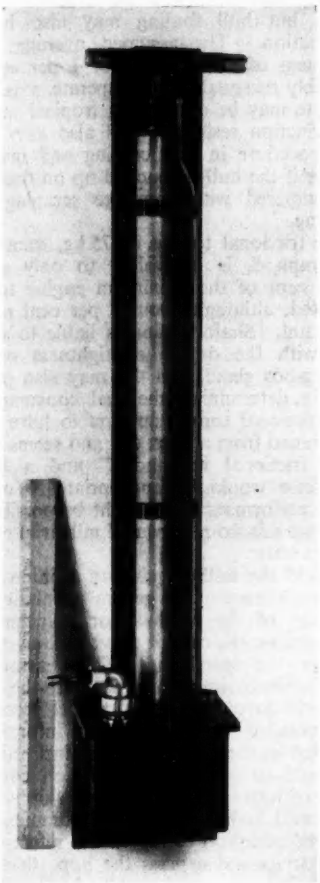


Fig. 9—350 atm thermal flowmeter, Mark III

flow, where the air convection heat-loss was of the same order as the heat supplied to the water. Hand operation also showed that the temperature bridge could be much more quickly rebalanced after a change of rate of flow if the Variac was over-adjusted and then brought back. This was very roughly equivalent to proportional plus first derivative control and suggested the use of a Brown air-operated controller. The Variac, however, required a large angle of rotation, which complicated its connection to a diaphragm air motor. Now a Selsyn motor can be used as a variable transformer, and as it requires a much smaller angle of rotation, it was substituted for the Variac. While the arrangement worked, it was both cumbersome and expensive and the purely electrical system described below was found to be preferable, although rather slower, since derivative control could not be included.

Final Model.—The circuit diagram is shown in Fig. 7 and the prototype flowmeter in Figs. 8 and 9. Subsequent experiments have shown, however, that it is desirable to incorporate a water jacket as in Mark II and this has been included in the final design. Referring to Fig. 7, thermometer windings of 42 S.W.G. platinum wire are used instead of nickel because the latter would act as strain gauges and change their resistances when the capillary expanded under pressure. The Wheatstone bridge circuit containing *A* and *B* is adjusted to balance at a temperature difference of 17 deg. Cent. and is fed with alternating current. This temperature difference must be maintained at zero flow and zero heating current in order to obtain a stable recorder zero. The 1in length of capillary inside the upper thermometer winding *A* is, therefore, heated by a current maintained at 1·7A by the type 1909 barretter *C* and an adjustable resistance. Any out-of-balance voltage in the bridge circuit is applied to the Brown phase-sensitive amplifier *D*, the output of which causes the Brown two-phase motor *E* to revolve in the appropriate direction. The motor drives a 5000 ohm logarithmic potentiometer *F* through a 160 : 1 reduction gear and a simple friction clutch, the latter being a safeguard against over-running. The potentiometer is logarithmic because the cooling effect of the fluid is slow at low rates of flow and the heating current must, therefore, change slowly if violent hunting of the recorder is to be avoided. The output voltage of the potentiometer increases more and more rapidly as the flow rate rises, thus making the speed of response of the flowmeter as high as is possible without first derivative control. The Brown a.c. recorder is fitted with a special input circuit (see Fig. 7) which gives a response to the square of the input voltage as shown in Fig. 12. The response can be made practically linear by using two slide wires, but the additional cost and complication were considered to be unwarranted. The range is adjusted by means of the variable 500 ohm resistance in the Brown recorder input circuit (Fig. 7.)

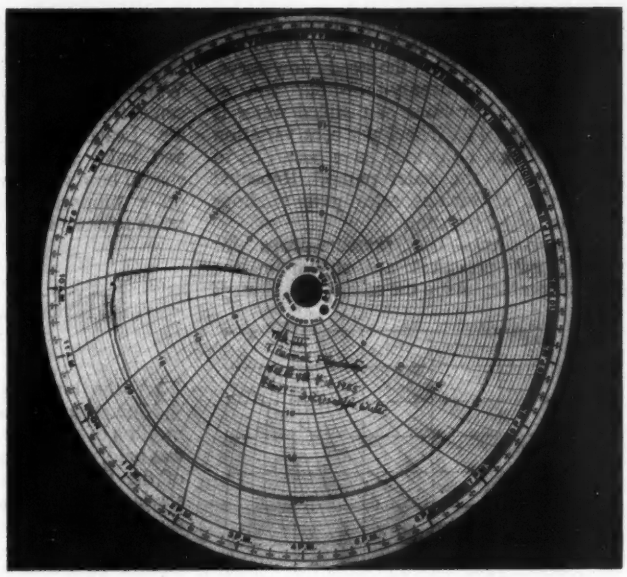


Fig. 11—Twenty-four-hour record at 320 millilitres per hour of water. Mark III thermal flowmeter

As in the case of Mark II type, Mark III cannot be used for electrically conducting fluids.

Performance

Steady Flow.—Calibration curves for gas and distilled water are shown in Fig. 10. The steady flow of water was obtained from a constant head tank and the curve was taken at increased sensitivity in order to show any difference between it and the pulsating flow calibration. The range can be extended to 700 millilitres per hour of distilled water and 3·5 cubic metres per hour of gas.

Pulsating Flow.—As the calibration was linear with respect to the recorded square of the heating current, it was expected that the calibration would be unaffected by pulsating flow. This was confirmed by feeding the water from a variable stroke,

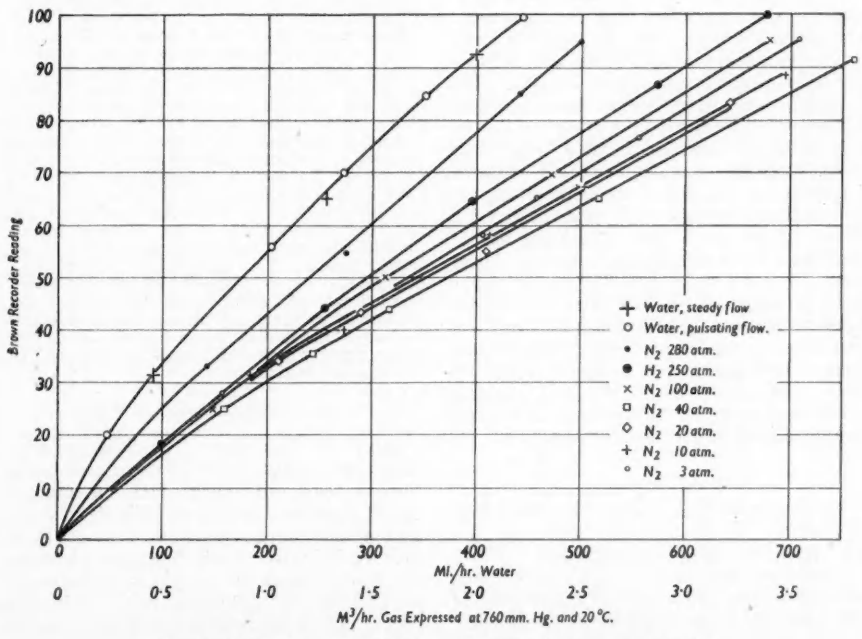


Fig. 10—Calibration of Mark III thermal flowmeter on gas and water

single cylinder, single acting pump, running at 28 r.p.m. It will be seen there is no significant departure from the steady flow curve. A record of a twenty-four-hour run at 320 millilitres per hour of distilled water is shown in Fig. 11. The 2 per cent variation during the first hour may have been due to air bubbles in the water pump. Repeated short runs at various rates gave readings accurate to ±1 per cent.

Pressure-Drop.—The pressure-drops for various gas pressures are shown in the following table. As in the case of the Mark II

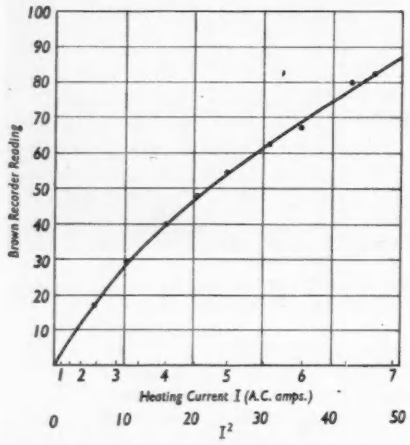


Fig. 12—Calibration of modified Brown recorder against avometer

flowmeter, the values may be very different for capillary tubes of the same nominal bore, but taken from different production batches.

Gas	Inlet pressure	Rate of flow, m³/hr	Pressure drop
Nitrogen	75 lb per square inch	2·6	23 lb per square inch
Nitrogen	10 atm	2·4	¼ atm approx.
Nitrogen	20 atm	2·9	½ atm approx.
Nitrogen	50 atm	3·0	0 on gauge
Nitrogen	100 atm	2·3	0 on gauge

There has been no opportunity yet for a plant trial.

Conclusion

Three types of thermal flowmeters for pressures up to 350 atm have been produced. The first differs little from a known low pressure type, but its range is only 4·5 millilitres per hour of liquid and 14 litres per hour of gas (expressed at N.T.P.). The second, Mark II, is heated by a constant current of 6A, and has a range of 0–180 millilitres per hour of distilled water and 0–900 litres per hour of gas at 250–350 atm (expressed at N.T.P.). Above these rates it is necessary to use the more expensive Mark III, in which the temperature rise of the fluid is automatically controlled at 17 deg. Cent. It has a range of 0–700 millilitres per hour of water and 0–3·5 cubic metres per hour of gas and its calibration on liquids is unaffected by pulsating flow. Experiments have shown that larger models of Mark III can be made to meter up to 3 litres per hour of distilled water. Marks II and III are not suitable for electrically conducting fluids.

Appendix

Cementing Nipple to Capillary Tube with "Araldite" Cement.—Heat and draw out an "Araldite" stick to a pencil point. Clean the capillary and coat it thinly by rubbing the "Araldite" point on the heated end of the tube. Bake for ten minutes at 240 deg. Cent. Allow to cool and apply a second, thicker, coat, but do not bake. The bore of the nipple must be about 0·016in larger than the outside diameter of the capillary. Warm it and slide it up and down over the cemented capillary to get rid of any entrapped air. Leave the nipple in the required position and bake again as before. The capillary should be vertical, with the nipple end resting on a support while baking, otherwise air tends to enter the joint.

The joint should stand a test pressure of 520 atm (hydraulic).

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Institution of Naval Architects

AUTUMN MEETING—No. I

BY the kind invitation of the Yugoslav Society of Naval Architects the autumn meeting of the Institution of Naval Architects was held, under the patronage of the President of the Federal Peoples' Republic of Yugoslavia, Marshal Josip Broz Tito, in Yugoslavia. The delegates were welcomed at an official reception in the Kvarner Hotel, Opatija by Professor S. Silovic, who apologised for the absence of Ing. A. Jagondik, who was prevented from attending by illness. Vice-Admiral Jerkovic, representing Marshal Tito, also warmly welcomed the members, as did also Mr. Raote Kesic, on behalf of the Yugoslav Shipping Association, and the Mayor of Opatija. In reply, Sir Harold Yarrow first gave a message from Lord Runciman, who expressed his regret in not being able to be present owing to business commitments at home, and then went on to thank the Yugoslav Society for making it possible for our naval architects to hold their first meeting in Yugoslavia. He also thanked Professor Silovic for all the preparations he had made for the comfort and entertainment of the members of the Institution and their ladies, and thought that such meetings were of considerable importance in the improving of international relations.

The meeting was continued on the morning of Tuesday, September 20th, with the reading of technical papers at the Palme Hotel with Mr. R. B. Shepheard in the chair. The first paper presented was :

MEASUREMENTS ON M.V. "RIJEKA," WITH THEIR ATTEMPTED PRACTICAL APPLICATION

By Professor Ing. Silovic and Ing. N. Fancev

Synopsis

The paper has the practical aim of using the results of measurements carried out on board the ship for making them an instrument for control of fuel consumption as well as for the analysis of the ship performance in service. The particulars of M.V. "Rijeka" are given, together with the resulting measurements and other data, and also the method of preparing the generalised power and fuel consumption diagram. The daily fuel consumption (D.F.C.) diagram is introduced which makes it possible to read off directly the daily fuel consumptions from the known mean daily speed of the ship and the revolutions per minute of the propulsion machinery. The fuel consumption given in the engineers' reports for three sister ships and taken over a period of two years, are compared with those taken from the D.F.C. diagram and shown to give satisfactory agreement. The influence of weather conditions on speed and revolutions per minute is illustrated and an economic analysis of the ship in service is given for various speeds, weather conditions and deadweights, as well as for certain fixed expenses.

Discussion

Dr. R. W. L. Gawn : The daily fuel consumption diagram seems of merit as a basis, since it bears out voyage data. It appears that the recorded consumption is about 2 per cent greater than calculated for passages from the Adriatic to North Sea ports, but on Far East voyages the margin is increased to about 8 per cent. Reduced engine efficiency due to higher temperatures and perhaps less favourable sea conditions may contribute to the greater fuel consumption on the eastern route, but hull fouling may also be an explanation. The assumed average daily increment of skin friction of $\frac{1}{8}$ per cent is probably reasonable in temperate seas, but the rate may be doubled in tropical waters. Skin friction resistance will also vary with the procedure in hull coating and may be greater if the hull is touched up on docking, as compared with complete scraping and painting.

The frictional torque of 75 kg, quoted in paragraph 5, is equivalent to only about $\frac{1}{2}$ per cent of the maximum engine torque recorded, although about 2 per cent of the minimum. Shaft friction is liable to variation with the degree of tightness of the stuffing-box gland, and this may also play a part in determining the fuel consumption. The frictional torque appears to have been determined from a dock test and seems to be the "frictional remainder" and a larger allowance would be appropriate to operational performance. It might be possible to elucidate this from measured mile trial results in calm water.

Would the authors give an opinion from their experience of the general reliability and accuracy of the Maihak torsionmeter and comment on the overall accuracy and operation of the speed log. Those associated with measurements on ships realise the effort and skill involved in the careful recording and detailed analysis of the information included in the paper and our Institution is fortunate to have a paper which contains much of interest to shipowners, shipbuilders and naval architects. May I commend the authors' attention to my earlier reference to speed trials and express the hope that they will include the trial results in the paper, together with those of the relevant model tests.

Professor Dr.-Ir. W. P. A. van Lammeren : The authors have given an interesting series of results of a ship under service conditions. Similar good results are scarce and, therefore, the N.S.M.B. is interested in them, particularly because a model of the M.V. "Rijeka" was tested in our establishment.

I shall first make a critical survey of the results given in Table I and then compare these results with the predicted results and trial trip results. Furthermore, a comparison is possible with the results of the propeller in open water conditions. The results in Table I of the paper are plain. However, from their Fig. 2 the authors have drawn the conclusion that a number of them must be wrong, but the deviations found can be explained by the resistance log when towing.

Though I appreciate the open and uncomplicated treatment of the results, I think that a stricter selection of the measured results is possible. Assuming that the measurements of revolutions per minute are reliable, we can detect wrong speed measurements by plotting revolutions per minute on the base of speed and this can be done in one figure

for different displacements by correcting revolutions per minute by a percentage equal to one-quarter of the percentage difference in shaft horsepower. The latter may be accepted as varying with $\Delta^{2/3}$.

The results, with reliable speed measurements, may be divided into three groups : Fine weather : (*a*) those corrected to a standard displacement of 6232 tons, for which model experiments were carried out ; (*b*) those for the smallest displacement, uncorrected, and (*c*) those measured during bad weather.

Unfortunately, no self-propulsion tests were carried out with a model of the " Rijeka " fitted with a model of the present screw; therefore, the results of the self-propulsion tests could not be compared directly with those of the ship. From tests with a different propeller of the same revolutions per minute and approximately the same diameter, the effective wake fraction as well as the thrust deduction fraction and the relative rotative efficiency are known and by applying these values to the " B "-series propeller of the M.V. " Rijeka " it is possible to make a prediction for this ship in the present condition. From this prediction we give the average allowances on the tank condition and in our opinion the agreement for fine weather conditions is satisfactory, especially if we take into account the fact that the measurements were taken from ten to twelve months after docking.

Furthermore, we give the results of trial trips with the M.V. " Zadar " and the M.V. " Pula," during which the weather number was about 80. Unfortunately no trial trip results of the M.V. " Rijeka " are available, and the differences between trial and service results may be explained by differences in the surface roughness of the hull.

If we restrict ourselves to values found under favourable weather conditions and the bigger displacements, the picture may become different. We also calculated the relation between Q/N^2 and V/N for the screw under consideration from the open water diagram for several values of ψ and found that $\psi = 0{\cdot}25$ was in good agreement with the ship data. This value also agrees well with the value of $0{\cdot}26$ which was found for the model. Scale effect in frictional wake can account for this small difference. However, there is also an appreciable difference in slope between $Q/N^2 - V/N$ curves derived in this way and the curves given by the authors. It would be interesting to investigate how far this different slope might influence the surprising result mentioned in section 7, namely, that the diesel engine would have delivered a constant output with the fuel control lever in a constant position and changing weather conditions. We should be very pleased to hear the authors' opinion on this.

Professor Dr.-Ing. K. A. G. Kempf : The particular aim of this paper is to afford the shipowner a reliable basis for the daily fuel consumption of his ship under average service conditions, and this has been achieved by the results and has also shown what the tank can do for the shipowner. The difference between the calculated average and the reported daily fuel consumption leads one to ask whether the weather were more than usually adverse or if the hull skin had deteriorated, or if something was wrong with the propeller or with the machinery.

If it were the weather, it would show the log book, plastic prints taken under water while the ship is in harbour could check the hull surface, while the propeller could be inspected by divers, and indicator diagrams referred to concerning the engine.

All measurements on ships should be carried out by the same methods with the measuring devices, under continuous supervision by a trained staff, for only under such conditions can we obtain valuable information such as that given in their paper.

Mr. A. R. Mitchell : The amount of labour involved in compiling the service performance data in this paper has been very great and an analysis of the data, together with its ingenious application in the charts, is worthy of commendation. The only weak link is in the admitted inaccuracy of some of the speed figures recorded by the resistance log. It is stated that this method reveals immediately the points containing those errors of measurement which do not result from the standard inaccuracy of the instruments, but from other causes. When compiling our trial data the engineers are anxious to impress with the accuracy of their figures of power obtained with their torsionmeter, the revolutions shown by their counters, and their fuel consumption figures, while our times on the measured mile are measured to fifths of a second. In service conditions this is not possible and we depend on the log, which gives a very good estimate of the speed, but is subject to tide effects. Do the authors take checks of this speed on the known distance between certain ports ?

This paper is of greater interest to the shipowner than to the shipbuilder, for it enables the shipmaster to ascertain what the fuel consumption will be if the displacement of the vessel and the weather intensity are known ; but it is also of interest to the ship designer, for data of this type are most difficult to obtain.

The figure of 62 per cent given for the time spent in harbour appears to be high, but I notice in Dr. Corlett's paper on the design of economic tramps that he gives a figure equivalent to 55 per cent, so that the authors' figure of 62 per cent seems not unreasonable.

Ir. A. J. W. Lap : Professor van Lammeren has referred to the peculiar result of the diesel engine delivering a constant output instead of a constant torque with the fuel control lever in a constant position. Indeed, one would expect the torque to remain constant when the same quantity of fuel is injected per revolution. To get an idea of the behaviour of the torque in this particular case I plotted the torque values, given in Table I, on a base of the position of the fuel control lever, and in this way discovered that the delivered torque corresponding to a certain position of the fuel control lever decreases with time. For this phenomenon several explanations are possible. In the first place, it is possible that something was changed in the mechanism of the fuel control. However, the plotted results give the impression that the change occurred gradually, and after the fourth day a stable condition was attained. A second possibility—of academic value—is that the efficiency of the engine was decreasing or that the calorific value of the fuel was decreasing with time. A third possible cause is a change in the zero calibration of the torsionmeter. At the N.S.M.B. we have had much experience with the Maihak torsionmeter and we know that a wandering of the zero calibration is possible unless effective measures are taken to prevent inherent stresses in the apparatus. Therefore I ask if the authors have had the opportunity to calibrate the torsionmeter during their trip on the M.V. " Rijeka," and, if so, whether the results can elucidate the phenomena mentioned.

Dr. E. C. B. Corlett : In their economic analysis the authors conclude that the ships in this service at high permanent costs (group B) never reach their economical speed at all, not even under ideal weather conditions. Mr. Mitchell has commented on the time which ships spend in port. I would like to ask the authors to consider reducing the figure of 62 per cent as the time spent in port to 55 per cent, and to estimate the effect on the economical speed of the ships, because if it is possible to turn round more quickly that is a much more economical way of making the ships return their costs more easily. I suggest that, taking the ships at their present designed service speed, they estimate the percentage of time spent in port that would enable those ships to retain their economic speed.

Mr. J. D. Calder : I notice that dockings of the M.V. " Rijeka " took place on March 13, 1953, and April 24, 1954, and ask if that is the usual interval between dockings. I have had considerable experience in ships in the Eastern Mediterranean, and have found it much more profitable to dock ships at intervals of six months rather than intervals as long as that mentioned in the paper.

With regard to the suggestion by Dr. Corlett that ships do not earn money in port, I disagree, because the purpose of the ship is to carry cargo, and how can she carry cargo if she does not load and discharge it ?

D. Gospodnetic : There has been discussion on the Maihak torsionmeter and other instruments used in this work. The Maihak instrument has the advantage of being purely mechanical ; electrical instruments are perhaps much more sensitive, but are not so accurate. The pick-up of a torsionmeter might stick momentarily, and the recording instrument does not average the torque per revolution, but in some cases that is not important. About speed measurements, we have not an instrument which will satisfy us completely, but I hope that the Kempf log can be further improved by eliminating the effect of the towing wire.

The second paper read on Tuesday morning was :

THE PITCHING AND HEAVING OF SHIPS

By A. J. Sims, O.B.E., R.C.N.C., and A. J. Williams, R.C.N.C.

Synopsis

The paper attempts to do two things—to produce a parallel approach to pitching and heaving to the classic theory of the rolling of ships and to provide a tool to enable the experiment tank worker in this field to analyse model experiment results. To this end the theory of pitching and heaving has been re-examined with a view to a clearer understanding of model experiment results and sea-going behaviour. New parameters are evolved, using wave slope and height parameters qualified by conversion factors which depend upon the geometry of the ship's form and the ratio of ship length to wavelength, and a method is proposed for plotting experimental model data in a form compatible with oscillations theory and suitable for the more critical examination of data obtained. The results of treating some model data are described and discussed. The recommendation is made that model results be presented both in the proposed and in the conventional manner as complementary forms.

Discussion

Professor Sir Thomas H. Havelock : The authors have developed a fresh idea and have succeeded in giving a new look to the familiar classical theory of heaving and pitching. That theory is inadequate to deal with the problem completely, and needs modification and extension in many ways ; but it is of little use attempting to build upon it unless it is soundly based and gives a reasonable first approximation. It has at times been criticised unduly, but that was due partly to the manner in which the results were presented, and the present paper is therefore very opportune. There are various details in the development which might be discussed, but the kernel of the paper is equation (x). Hitherto the factor ϕ has been

on the right-hand side of this equation. If it is brought over to the left, as in (x), then the right-hand side is, in the main, independent of the form of the ship and of the wavelength ; hence, the ratio μ on the left-hand side must also be independent of form and wavelength.

Thus, we get a single curve, one of the well-known response curves produced in Fig. 4, and this is brought out in the diagrams, especially in Figs. 8 and 9 for pitching, which justify the authors' conclusions on the soundness of the simple oscillation theory. No doubt the theory could be improved. The important point is the calculation of the function ϕ from the forces and moments acting on the ship, which is troublesome for a normal ship form even on the present basis ; however, one would like to see some attempt to take account of the disturbance of the wave pressure system caused by the ship, and including, if possible, the effect of speed of advance. There is the question of the coupling of heaving and pitching, but these are matters for future development and the best line of attack may well be indicated by further experience with the new method of presenting the results of the approximate theory.

Dr. R. W. L. Gawn : Firmer understanding of pitch and heave oscillations is essential if the growing emphasis on improved steadiness and sustained speed at sea is to be fruitful of results. Our conception of rolling has long been substantially clear, and much of the experience with ships at sea can be explained by the simple linear theory. This is largely due to the circumstance that the waves of real interest are long in relation to the beam of the ship. There have been mathematical solutions of pitch and heave, but factual application to ships has been limited by a number of complicated factors. One stumbling block is that the length of ocean waves which promote objectionable motion is more or less commensurate with the length of the ship. The authors have surmounted the difficulty by developing an analytical theory based on the static amplitude.

Fig. 7 (in the paper) shows agreement between calculation and experiment, but detailed examination indicates that the two sets of curves are practically indistinguishable at the extremes of large and small amplitude, but the calculated motion is greater in the middle zone by about 10 to 15 per cent, depending on speed and tuning factor. It would be instructive if the authors could give the modification necessary to the damping and inertia coefficients for closer agreement in this region. Detailed exploration should prove rewarding, as the zone concerned is that of greatest operational interest, since it represents the conditions most frequently experienced at sea. The latter is not fully apparent from Fig. 7, but would be evident if a wave factor base were substituted for tuning factor. The results would throw light on the increase of damping required to effect a worthwhile degree of stabilisation in this zone—say, a reduction of 20 per cent or more of amplitude. A fairly substantial change in hull form with perhaps a modification of radius of gyration would probably be involved.

Fig. 12 indicates that the motion at the stern is much less than at the bow. This is important operationally for aircraft carriers, since the range of sea conditions under which an aircraft can land on the flight deck is thereby increased. The characteristic arises from the phase difference of pitch and heave, and special attention is now given to this in model experiments, the movement both of bow and of stern being measured direct as well as the pitch and heave and the phase of the oscillations. The results of some model tests afford some support for the claim that the phase difference may be 90 deg. under certain conditions and thus conducive to minimum stern motion. Moreover, Sir Thomas Havelock, in his recent paper, has shown this to be theoretically true for a mathematical shape in still water. Model tests at Haslar have also indicated departures from 90 deg. phase up to about 30 deg. or more, depending on the speed of ship and length of wave. This reacts on the limitation of stern motion and there is accordingly scope for further investigation of phase difference both by theory and experiment.

The dominance of length of wave in determining the amplitude of pitch and heave has been confirmed by model tests and is supported by the present paper. It is for this reason that results obtained at Haslar are related to the wave factor. The complete presentation proposed in paragraph 8 appears as important, for selected application ; any attempt to follow this generally would involve considerable effort and unduly expand investigations on seaworthiness, which already entail a lengthy effort in analysis, particularly with additional measurements, such as acceleration and slamming. It is complementary practice at Haslar to relate results to the tuning factor, but the virtual mass is neglected, as this quantity is largely unknown, and even for a given ship it appears to be variable and to depend on the speed and the state of the sea.

Professor Dr.-Ing. W. P. A. van Lammeren : The references given in the paper do not go far enough back, but no doubt the authors know that some valuable contributions have been made recently by other scientists, such as Weinblum, St. Denis, and others, and I ask if the authors have taken the results of that other work into account. If so, can they tell us whether the results are in agreement with the results of their own work ?

Dr. W. Muckle : I find the paper interesting from the point of view of one who has to put over the theory of pitching and heaving to students, and the authors have given an excellent extension of the simpler theories. They have made clear the marked difference between the rolling problem and the pitching and heaving problem. Of course, the theory of rolling assumes that the breadth of the ship is small in relation to the length of the waves. In Fig. 1 a sub-surface wave is shown. Was the slope and height of this sub-surface wave used in the theory ?

Coupling has been mentioned by Sir Thomas Havelock and I would like the authors to expand their theory to include this effect. Do they think that the influence of coupling would be serious, and would it influence greatly the results they have obtained already ?

I am interested in virtual mass and damping equations. In Fig. 7 the curves have been drawn for an assumed k value of 0·3 and I ask on what was that assumption based, or how was that k value derived ? In connection with virtual mass in this complicated moment of the ship, we know that we cannot have either pitching or heaving without the other coming into it and I think there are two different virtual masses, one for heaving, where there is a vertical bodily up and down motion, and the other for pitching, where there must be some three-dimensional flow of the water along the hull of the ship.

This work has enabled us to go a stage further in determining the influence of pitching and heaving on longitudinal stress. That matter is not dealt with directly in the paper ; but since there is close agreement between forecasts by this theory and what is likely to be obtained from model experiments, then we can calculate what would be the additional bending moment put on to the ship due to pitching and heaving. It is interesting to know that some model experimental work, on the determination of such bending moment in pitching and heaving, has been carried out both in America and Japan.

Mr. Sims, replying to the discussion, said : Sir Thomas refers to the improvements which may be made. We are conscious of the fact that the full hydrodynamics of the system around the ship are not quite as we have assumed in the paper. It would be delightful if other factors could be taken into account in the calculations. We have had to assume that the behaviour of a ship in a wave system does not alter the pressure system indicated by the simple wave theory and would like to take account of the modification of the wave system through the presence of the ship and modify the theory to that extent. It would be helpful if anyone could find a way to determine this modification. There should, however, be only a second order correction on the results obtained.

One or two speakers have mentioned the coupling of the pitching and heaving systems. We have had to assume that the two actions can be considered separately and then superposed and the results so far achieved encourage the belief that this approach is reasonable. It is not claimed that the phase difference is exactly 90 deg., and I hope that other workers will be able to satisfy our curiosity as to the actual phase difference between pitch and heave.

Dr. Gawn mentioned the divergence in the middle of Fig. 7, and I agree that this is the important part of the diagram. The difference may be due to a variation of the damping factor, a variation of the virtual mass, the introduction of damping varying as some other power of the velocity, or simply to the fairing of the points obtained experimentally. The method we have outlined should enable those factors to be more clearly appraised in future experiments. With regard to the changes required to achieve improved damping, Fig. 8 gives the results obtained with shallow waves and with deeper waves. This gives some opportunity of assessing what variations in a ship's form away from the water-line will do, and illustrates one of the advantages of the method. The lower curves in the figure illustrate the extra damping provided by such factors as flare forward, stern shape, and so on, when the ship is pitching heavily, and the experimenter can thus be more certain of what he is getting by trying variations in such features.

Dr. Muckle asked why we have chosen $k=0{\cdot}3$. We have done no more than choose a linear damping coefficient which most nearly brings the two diagrams into harmony. We do not claim that the damping factor is steady at 0·3 ; indeed, the method we have produced will, we hope, enable tank investigators to examine such variations, make sure that any such change in the value of k is actually taking place and ask themselves what is the nature of the change.

It is not considered that longitudinal stresses should be investigated by this method as a routine calculation but there are increased possibilities in this direction. The method also helps in the occasional investigation which has to be made into stabilisation against pitching and heaving.

(To be continued)

International Motor Show at Frankfurt

No. I—PASSENGER CARS

THIS year's "Internationale Automobil-Ausstellung" at Frankfurt a/M, which took place from September 24th to October 2nd, was the thirty-seventh German Motor Show and the third organised since the war. The Show, which is now being held biennially, was significant in so far as, for the first time, it was scheduled ahead of the Paris Salon and the London Motor Show, thereby providing the first of the three international shop windows which can be seen this autumn.

A large number of visitors, among them a considerable number of foreign buyers, crowded the sixteen exhibition halls, which now cover an area of almost sixteen acres; a further eight acres of open-air parks were allotted to heavy vehicle demonstrations and to all sorts of equipment in actual operation.

TABLE—*Production and Exports of Motor Vehicles in the First Six Months of* 1954 *and* 1955

A.—Great Britain (exports in 1955: 43 per cent of total production).

	Motor-cars		Per cent increase	Commercial vehicles		Per cent increase	Total		Per cent increase
	1954	1955		1954	1955		1954	1955	
Production	379,480	460,740	+22	128,394	165,876	+29	507,874	626,611	+23
Exports	187,939	200,360	+7	65,890	78,007	+20	253,834	278,367	+10

B.—Germany (exports in 1955: 46·5 per cent of total production).

	Motor-cars		Per cent increase	Commercial vehicles		Per cent increase	Total		Per cent increase
	1954	1955		1954	1955		1954	1955	
Production	263,992	360,622	+38	59,275	72,075	+22	323,197	432,697	+33
Exports	103,510	172,069	+60	28,101	30,295	+8	131,611	202,364	+53

As in former years, the largest manufacturers, like Mercédès-Benz, Ford, Auto-Union, Volkswagen and Bosch, had their own exhibition halls, which on this occasion were generally decorated with greater restraint and with decidedly better taste. Apart from some thirty German motor manufacturers, showing a great variety of motor-cars and commercial vehicles, there were four American firms, four French, two Italian and one Czechoslovak exhibitors. The British contingent in the car section consisted of fourteen makes, including most cars of the British Motor Corporation, the Rootes Group, Ford and Standard, while the commercial vehicle industry was represented by Commer.

The German Motor Shows nowadays are of particular interest to the British visitors, for in the last two years German motor manufacturers have proved to be the strongest competitors of the British industry, not only in the chief Continental markets, but also in such overseas markets as Argentine, Brazil, Chile, South Africa and, lately, even the United States of America. The above table shows the German production and export figures for the first six months of this year, compared with those of the same period, 1954. It also shows the corresponding figures of the British motor industry.

The German motor industry at present produces at the rate of about 3500 vehicles per day, i.e. the total production figure is about 70 per cent of the British production. Exports of vehicles amount to 46·5 per cent of the total production, an increase of 53 per cent compared with the same period in 1954. A steep rise of 60 per cent in exports has occurred in the class of motor-cars, while the increased production of the commercial vehicles is largely being absorbed by the home market.

The considerably increased exports are due to a variety of factors. There is little doubt that the successive victories of Mercédès-Benz in Grand Prix racing and those gained by D.K.W. and Porsche in other international sporting events have proved to be a very successful form of industrial propaganda which has furthered the prestige of the German motor industry as a whole. Another factor which in future might have even greater influence on export sales is a certain flexibility of the German motor industry which can offer a great variety of technical features which, though considered unorthodox in this country, seem to appeal to many foreign customers.

We mention in this connection such constructions as independent all-wheel suspension, front wheel drive, two-stroke and air-cooled engines. These remarks, of course, apply only to those factories which are not affiliated to the big American concerns of Ford and General Motors. The export sales of such firms as the Cologne Ford Works and of Opel, both of which still produce the more orthodox type of car, however, are largely controlled by their American parent companies.

The question whether or not the German motor industry will be able to intensify its export drive is difficult to foretell and will depend greatly on the development of the domestic market. Although the number of vehicles per head of population is still smaller than the corresponding figures for Great Britain and France, it is gradually approaching saturation point. Since the last motor show in March, 1953, about 1·6 million new motor vehicles have been registered in Germany, among them approximately 650,000 private cars. Traffic conditions, therefore, have become very similar to those prevailing in this country. Roads as well as streets in big towns are badly congested, though the traffic itself seems to be faster and more flexible, since the great majority of pre-war cars have now been replaced by vehicles of much better acceleration. The incidence of accidents is just as bad as, or even worse than, in this country, and public opinion urgently calls for substantial improvements of the inadequate road system.

Though motor manufacturers are generally optimistic and hope that by further efforts the export rate can still be increased, there are many economists who advise greater restraint, particularly in the prevailing policy of buoyant expansion and lavish capital expenditure. They point out that for political or economic reasons over which the industry has no control, the current demand may drop considerably so that the greatly expanded manufacturing capacity of many firms may not be fully utilised. Aggravating circumstances are the shortage of skilled labour and the scarcity of certain raw materials, such as steel and, particularly, of coal, a considerable amount of which has to be imported from abroad. A redeeming feature seems to be that some firms, very sensibly, are spending large sums on research and development, thereby trying to anticipate any changes which are likely to occur in the public demand in order to produce,

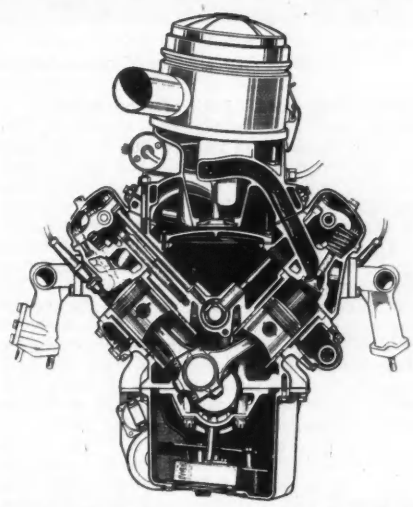

Fig. 2—The camshaft of the B.M.W. V-8 engines runs in an oil bath. The oil is cooled by a heat exchanger visible in the port side water manifold

at short notice, vehicles to suit these conditions.

In these circumstances it is natural that German automobile engineering should now have passed the phase of outstanding new developments and has settled down to a stage governed by steady, though less spectacular detail improvements. The visitor who used to take it almost for granted to be faced at each German motor show with a number of novel constructions, might probably be disappointed, because this year's Show did not present any revolutionary changes.

In the main, the greater part of the German cars at this Show differed only in detail from those seen at recent international motor exhibitions, though many have undergone that steady process of refinement and improvement which continues almost unnoticed as long as one particular type

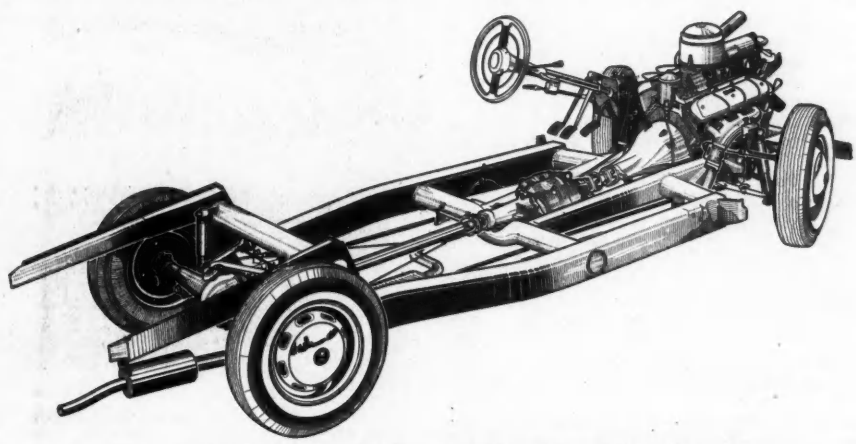

Fig. 1—The 2·6-litre B.M.W. 502 features the familiar rear suspension of the make

Fig. 3—The 1·9-litre Mercedes-Benz coupe has a four-cylinder single o.h.c. engine

is being produced. Lack of space prevents us from mentioning these minor alterations, frequently consisting of nothing but modifications in body styling, arrangement of instruments, radiator grilles, &c. There are, however, some models on show which are worth studying in detail and which are to be more fully described.

One of the surprises of the Frankfurt Show is the fact that the 3-litre Mercédès is no longer the biggest German car, at least not in so far as the cylinder capacity is concerned. The Bayerische Motorenwerke have marketed four different models fitted with 3·2-litre, eight-cylinder vee engines of 140 h.p. On this stand a beautifully styled two-seater roadster caught the eye, characterised by a particularly stiff all-welded frame, torsion bar suspension, and light-metal brake drums with shrunk-in cast iron liners (Fig. 1). It is claimed that this model is capable of a maximum speed of 140 miles per hour. The solid rear axle and chassis-mounted, remote-controlled gearbox of the " 502 " are retained.

Mercédès-Benz have adopted for all their current types of car the single-joint, low-pivot swing axle previously used only on the " 180 " touring car. Owing to the low roll centre which this particular design provides, the road-holding and cornering properties of all new Mercédès cars have been greatly improved. (Fig. 3). In order to satisfy the demands, particularly, of the export market, the 3-litre car now can be fitted with an automatic transmission of the Borg-Warner type, consisting of a hydraulic torque converter (with a maximum conversion ratio of 2 : 1) and two epicyclic gear trains. A further innovation is the adoption of petrol injection for the engine of the type " 300 S," a light two-seater sports coupé. By this means, the output of the engine, which has a compression ratio of 8·55 : 1, has been raised to the remarkable figure of 175 h.p. at 5400 r.p.m. All 3-litre Mercédès cars are now fitted with amply dimensioned finned light-metal brake drums, the brakes being operated by a vacuum servo mechanism.

Another interesting sports car is the Porsche roadster, powered by a four-cylinder, air-cooled horizontally opposed engine of 1·6 litre capacity (Fig. 7). The engine has two camshafts for each cylinder bank, light-metal cylinders and cylinder heads, roller bearings for the big-ends and the main bearings, and develops 75 h.p. at 5000 r.p.m.

The Ford factory of Cologne shows a new " Taunus M.15," equipped with a 1·5-litre, four-cylinder engine of 82mm bore and the very short stroke of 70·9mm. The o.h.v. engine has a compression ratio of 7 : 1 and develops 55 h.p. for 4250 r.p.m. An interesting detail of this engine is the nodular cast iron crankshaft with hollow main bearings, crank pins and crank webs. The oil channels are steel tubes with which the shell is integrated during casting. The hollow crankshaft weighs only 25 lb against 34 lb of the conventional type—a weight saving of 27 per cent. The total rotating weight has been greatly reduced and the balance of the rotating masses has been improved to such an extent that the peak load on the main centre bearing has been lowered from 2460 lb to 1840 lb.

Another car which has also been equipped with a new engine is the Goliath of the Borgward concern. The two-cylinder, two-stroke engine now has a capacity of 900 c.c. and is commercially marketed with a petrol injection pump (Fig. 5). It develops 40 h.p. at 4000 r.p.m., i.e. an output of 44 h.p. per litre. The above-mentioned Borgward concern has been doing quite well for the last two or three years: the 1·5-litre " Isabella " (Fig. 4), a well-designed modern car, with independent all-wheel suspension, is generally acclaimed as one of the best looking saloons and has greatly increased its sales.

The most remarkable and quite unexpected increase in production figures, however, was gained by the small Lloyd car of the same concern. This front-wheel-drive car, fitted with a 400 c.c., air-cooled, two-stroke engine, took third place among cars registered in Germany last year, and is produced at the rate of about 6000 per month. Instead of the two-stroke engine, the Lloyd is also available with a newly designed air-cooled, two-cylinder, four-stroke engine developing 19 h.p.

There seems to be a general tendency in Germany nowadays to abandon the motor-cycle in the sphere of everyday transport in favour of a vehicle offering better protection from wind and weather, while preserving as far as possible the advantages of low first cost, economy and cheap maintenance. The motor-scooter, which lately has become very popular on the Continent, is now considered only an intermediate step towards the small, low-priced, three- or four-wheeler

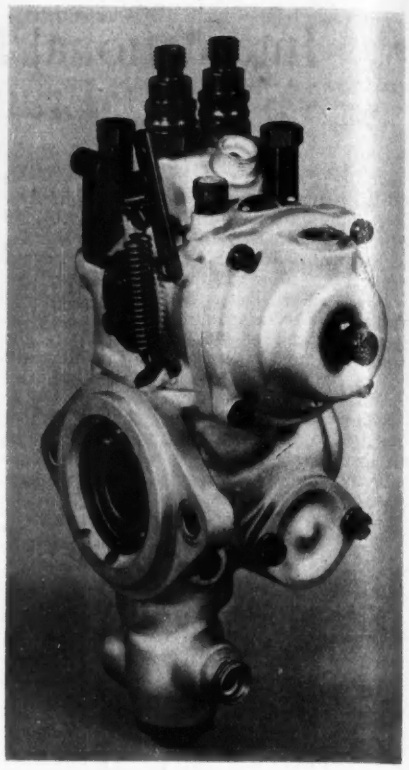

Fig. 5—The Bosch petrol injection pump for the Goliath 900 c.c. twin two-stroke

which offers full weather protection and seating accommodation for two or three adults, together with such amenities as heating, windscreen wipers and defrosters.

Several manufacturers, among them no less than three well-known former aircraft constructors, namely Dornier, Heinkel and Messerschmitt, are represented with vehicles described as " Kabinenroller " or " Rollermobil " (cabin-scooters), which are generally characterised by single or two-cylinder, air-cooled, two-stroke engines and 8in or 10in tyres. The arrangement of the transmission varies according to the general layout: three-wheelers have either a chain drive to the rear wheel or a front-wheel drive; four-wheelers either front-wheel drive or swing axles in conjunction with a rear engine.

The Messerschmitt three-wheeler (Fig. 6), already fairly well known in this country, is a well-designed streamlined vehicle with a tandem arrangement of the two seats, independent front-wheel suspension, and a 10 h.p. single-cylinder, 200 c.c., two-stroke engine, which transmits

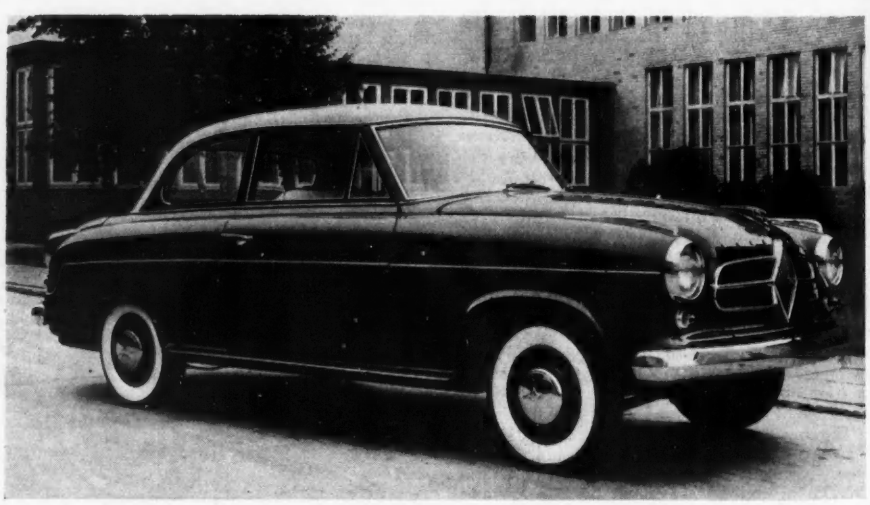

Fig. 4—The " Isabella ": Borgward no longer list an oil-engined car

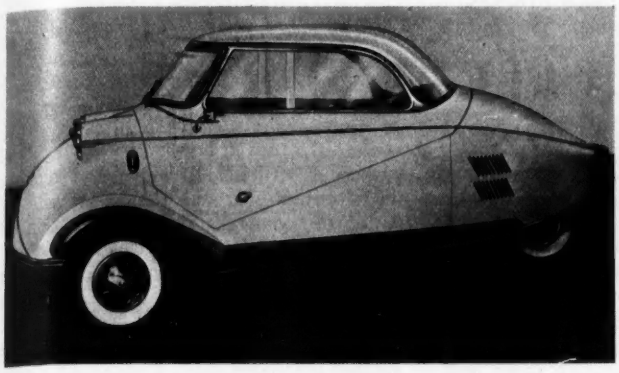

Fig. 6—The 200 c.c. Messerschmitt cabin scooter. The air-cooled two-stroke engine drives the rear wheel by sprocket chain

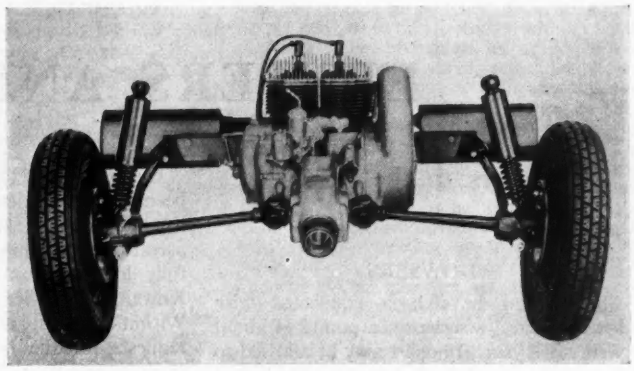

Fig. 8—The "Goggomobil" has crankcase, gearbox, cooling fan, and differential in one assembly

the torque over a four-speed gearbox and an enclosed chain drive to the rubber sprung rear wheel.

Other vehicles of the same class are the three-wheeler "Fuldamobil," the driven rear wheel having twin tyres, and the four-wheeler "Goggomobil" of Isariawerke, Munich, which is already being produced at the rate of about seventy-five a day. The "Goggomobil" (Fig. 8) is actually a miniature car with adequate seating accommodation for two adults and two children; it is powered by a 17 h.p. parallel twin two-stroke engine of 300 c.c. capacity, located at the rear, which transmits the torque through universally-jointed half-shafts to the coil-sprung wheels.

All the above-mentioned vehicles are fitted with electric starters and it is interesting to note that wherever single cylinder, two-stroke engines are employed, reversing is generally effected by starting the engine in the opposite direction by a reversible starter motor.

It is difficult to foretell whether or not these very small vehicles will ever become serious competitors to the small motor-car. In spite of their low weight, amounting to about 7 cwt or 8 cwt, they lack the acceleration and climbing capacity expected from a modern vehicle and might easily become obstacles in conditions of fast moving traffic. It appears doubtful whether the price of £250 (compared to approximately £350 of the lowest-priced, mass-produced car) will prove sufficiently attractive to create an adequate demand. Moreover, many of these vehicles are being made by small factories which, naturally, cannot offer the service facilities of the bigger firms.

This survey of German motor-car development would not be complete without mentioning the all-wheel drive cross-country vehicles which are frequently offered as "Jagdwagen" (shooting brakes) but which are actually cars of the "Jeep" type, designed for use by the police or the Forces. Vehicles of this type were exhibited at the stands of Auto-Union, Goliath and Porsche. Both the Auto-Union (D.K.W.) car and the Goliath are developed from the respective standard models of these firms and have the same engine and front-wheel drive layout as those types; they are fitted with differential locks and with an additional rear wheel drive which can be disengaged from the driver's seat (Fig. 9). The Goliath has a five-speed gearbox and the Auto-Union a synchronised eight-speed gear which enables this latter vehicle to climb gradients up to 6 in 10.

It is noticeable that, with very few exceptions, the specific output of engines (which in Germany is generally quoted as the horsepower available at the output shaft and, contrary to the S.A.E. practice, includes the power requirements of all engine-driven accessories) has gone up by about 10 per cent.

An output of about 35 h.p. per litre for ordinary production engines at speeds not exceeding 4500 r.p.m. is quite usual, and that of higher revving sports engines might approach 60 or more horsepower per litre. This considerable increase has been attained by higher engine speed, by raising the compression ratio up to 8·5:1 and by improvements to the volumetric efficiency by such means as suitable design of the inlet ports, new cam profiles and modified timing. In the majority of cases the increased output has been accompanied by a marked improvement of the torque characteristic, the maximum torque being almost constant in the most frequently used speed range between 1800 r.p.m. and 3000 r.p.m. The increased power is rarely utilised for obtaining a higher road speed but mainly for improving the power-to-weight ratio of the cars and, thereby, their acceleration and climbing capacity.

A good deal of research, largely carried out by research institutes attached to technical universities, has been devoted to the study of combustion and combustion spaces with a view to keeping the octane requirements of engines as low as possible. As a result, most German engines with compression ratios up to 7·5 : 1 run quite satisfactorily on ordinary grade petrol.

The demand for diesel engines for private cars has slightly dropped lately because of the considerable increase in the Government tax on diesel oil; nevertheless, the diesel engine is still considered the most economical power unit because of its favourable fuel consumption and its low maintenance cost. No noticeable development has taken place in this field, apart from the addition of an automatic injection advance to the 1·8 litre Mercédès-Benz engine, which resulted in smoother running and an increase of the output from 40 h.p. to 43 h.p.

It seems that the increase of engine speed and brake mean effective pressure have not adversely affected the reliability and longevity of modern engines. Improved materials and machining methods for cylinder bores, bearings, valves, &c., and new designs for pistons and piston rings have been employed to deal with the problems arising from higher thermal and mechanical stresses. Oil-water heat exchangers, generally arranged inside the water jacket, have proved useful to keep the oil at a constant temperature, thereby reducing cylinder wear to a considerable extent.

(*To be continued*)

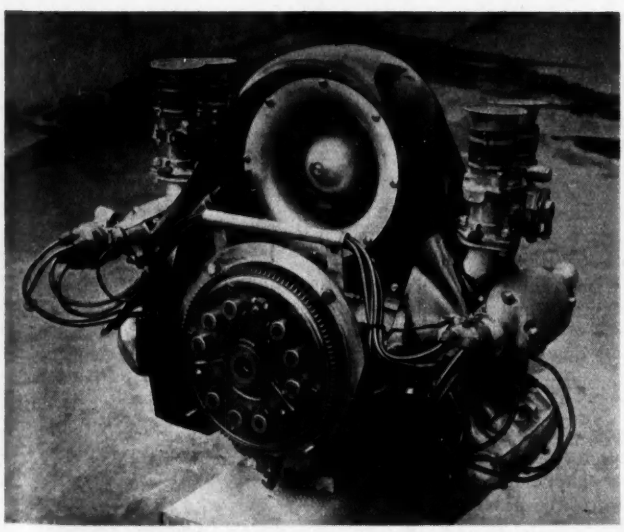

Fig. 7—The four-camshaft engine of the Porsche "Spyder" has dual ignition. Roller bearings are used on crank journals and pins

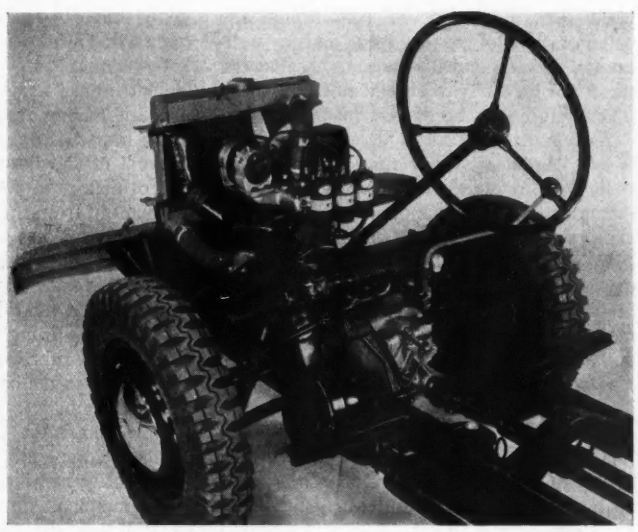

Fig. 9—The three-cylinder, water-cooled, two-stroke D.K.W. engine has now been incorporated in a four-wheel-drive cross-country vehicle

LETTERS AND LITERATURE

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

DOWSERS

SIR,—As I have been connected with dowsing and dowsers over a period of about twenty-five years, I hope I may be allowed to comment on the letters by Mr. Rolt Hammond and Mr. John F. Shipley in your issues of September 25th and 30th, respectively.

The muscular reflexes which the dowser experiences in the presence of water and minerals are the direct result of physical causes, probably of an electromagnetic nature. This can reasonably be assumed from the investigations carried out during the last thirty years or so, the results of which are contained in such books as *The Physics of the Divining Rod*, by Maby and Franklin, and *Psychical Physics*, by Dr. S. W. Tromp, and in sundry articles and pamphlets. The exact process by which the reflexes occur has yet to be elucidated.

Accurate dowsing depends not only on a special sensitivity but also on long training and experience, and hence it is that the number of really reliable dowsers is very small. A properly qualified dowser naturally studies the geology of the locality in which he is working, but geological knowledge is no guide to the position of water-bearing fissures, or to the exact spot in a water-bearing stratum where a maximum flow can be obtained. The trained dowser will, therefore, always be superior to the geologist. The use of many geophysical instruments is slow and laborious and the depth and yield of subterranean streams cannot be accurately found by their means.

The fact that dowsing is not used to a great extent in the discovery of oilfields in this country and in America is to be deplored, as much waste of labour and money would thereby be saved. The first oil well in Great Britain was developed through the collaboration of a geologist and a well-known dowser, and it is regrettable that the same dowser's advice should not have been taken before later bores were made.

As regards the United States, the *Bulletin of the American Association of Petroleum Geologists* for June, 1955, Vol. 39, No. 6, mentions that in the year 1954, 13,097 exploratory holes were bored, of which 2708 only were productive. The total of dry holes amounted to 45,791,944ft, which, at an average cost of 5 dollars per foot, means that in one year about 229 million dollars were spent in making dry wells !

It is a mistake to suppose, as Mr. Shipley implies, that the practice of dowsing is not worthy of serious consideration. Societies for dowsing, or radiesthesia, as it is now called, in its more general aspect, now exist all over free Europe, and the British Society of Dowsers has about 600 members in English-speaking countries, most of whom practice dowsing in one form or another.

During the last few years many wells have been located by dowsers in this country for local government bodies, institutions and private people, whilst water has been successfully located by dowsing in India, Persia, Kuwait, East Africa, Gibraltar, and Majorca. Within the last month I have had four requests for the help of dowsers, one of them on behalf of a Government department.

The "divine" nature of the dowsing faculty, to which Mr. Shipley refers, is sometimes taken too literally by the dowser's client, who, regarding his successful well as a gift from heaven, neglects to pay the dowser his well-earned fee.

The dowser, like any other honest craftsman, is worthy of his hire !

A. H. BELL

The British Society of Dowsers,
6, Portugal Street,
London, W.C.2.
October 10th.

RESILIENCE OF A GYMNASIUM FLOOR

SIR,—It will be remembered by your readers that in his original letter (THE ENGINEER, June 2nd) Mr. Cave-Brown-Cave sought to prove, on the basis of an experiment carried out by Dr. Wright and Mr. Roy, of Southampton University College, that there is no logical reason why a sprung gymnasium floor should be preferred to a rigid floor. Any such preference was, he maintained, "psychological and had no basis in physical fact." I questioned this conclusion and, in my letter (THE ENGINEER, July 22nd), gave reasons why the experiment referred to was ill-adapted to its purpose, the principal reason being that the smallness of the ratio of floor deflection to hip movement is in no way a measure of the effectiveness of a sprung floor in mitigating shock due to impact. I endeavoured briefly, by means of an example, to explain how it is possible to bring a body to rest by a quick succession of minor impacts against a yielding surface—each reducing the momentum of the falling body—rather than by a single and more violent impact against a rigid surface. The pleasant feeling that a resilient floor gives under impact is thus due, not so much to the "give" of the floor, as to the fact that it cannot deflect without causing a transfer of momentum from the descending body to the generalised masses that are associated with the "normal modes" of vibration of the floor. This explains why a thick rubber sheet spread over a rigid floor is in no way a substitute for a sprung floor, and also why the wearing of rubber-soled shoes is equally ineffective—in neither case is there a transfer of momentum.

A second letter has now appeared (THE ENGINEER, September 2nd) from Mr. Cave-Brown-Cave in which he seeks to show that, in the matter of impact force, the benefit to feet and legs (the main benefit in my view) is just as negligible as that to the upper part of the body. The argument he uses for this purpose is of doubtful value. One receives the impression that he is unfamiliar with the notion of "generalised mass," and has not in consequence fully appreciated the argument put forward in my letter. Without wishing to turn this letter into a lecture on the dynamics of impacts, I would like to point out that a resilient floor has an infinite number of generalised masses, one for each of its normal modes. If the period of a particular mode of vibration of the floor is short compared with the time during which the impact of the dropping body (or parts of that body) builds up to its maximum value, there is no relief due to transfer of momentum. Relief is obtained only for those modes of vibration whose periodic times much exceed that of the impact build-up time. For, to make the transfer of momentum effective, it should take place well within the first quarter period of vibration.

This lack of appreciation of the dynamics of the problem has led Mr. Cave-Brown-Cave to assume that the ball of the foot is the only part of the body that can possibly benefit from the principle of momentum-transfer, the heel and its associated leg masses being, in his view, completely insulated by the elasticity of the arch of the foot. According to the principles explained above, this view cannot be accepted. For, in a 3ft jump to the floor, the heel movement due to flexing of the arch at the moment of impact is only of the order of ½in, a distance which at an average velocity of about 8ft per second is traversed in a time of 0·005 second. This appears to be well within one quarter of the fundamental period of the floor (assumed supported by rubber blocks pitched some 4ft apart) which, from the figures given by Mr. Cave-Brown-Cave, should be of the order of 0·06 second. From the same figures the weight of an area of floor 4ft square is 64 lb. The generalised mass for this area of floor is, however, not 64 lb (as Mr. Cave-Brown-Cave implies in his letter), but, by reason of the form of displacement, only about one-quarter of this, i.e. 16 lb. Since this is less than the weight of the lower part of the legs, it should ensure a useful amount of momentum-transfer at impact, and therefore a welcome reduction in the final shock.

I will not follow Mr. Cave-Brown-Cave into a discussion of the economics of the situation—whether, for example, it is better to have a gymnasium with plenty of equipment but no sprung floor, or with a sprung floor and no equipment. I must, however, in the name of common sense, protest against his explanation of the reason why dancers like a sprung floor. "It is intended," he says, "to respond to the synchronous movement of a large number of people and to *pull them into accurate unison*" ! (my italics and interjection mark). Why not save money and dispense with the band ?

D. WILLIAMS,
D.Sc., M.I.Mech.E., F.R.Ae.S.

Farnborough, Hants,
October 7th.

Literature

Expansion or Explosion. By ANTHONY VICKERS. 1955. London : The Bodley Head, 28, Little Russell Street, London, W.C.1. Price 6s.

IT is particularly timely that this book should have appeared in this particular year. For its main theme is economics, and the reactions of human beings to economic factors. It is, however, not concerned with the intricate machinery of economics such as the relationships between bankers' deposits and advances, the offering of Treasury Bills and the like. Instead, it deals with the fundamental issues. It is, in short, not concerned with the detailed methods of expanding or contracting credit but is designed to discuss the effects upon individuals as well as upon nations of doing so. That the machinery is available and effective is " taken as read." Since it is, in fact, discussing the very factors that a Chancellor of the Exchequer should have in mind—not to speak of industrialists and trade union leaders—when, as now, symptoms of inflation are apparent and there is a lack of balance in this country's oversea trading ; and since it is also eminently readable and written in simple language, it is a book that is well worth having. When it is added that the author is an engineer and is particularly well aware how the work of engineers in improving materials and multiplying human output has influenced economics it will be seen how attractive the book should prove to readers of this journal.

The main theme of the book is that money in circulation should be adjusted to ensure that all that is produced can be consumed. It is regarded as a case of the tail wagging the dog when a former Chairman of the Federal Revenue Board of the U.S.A. can say: " The fact must be recognised that, however desirable on general principles continuous expansion of trade and industry may be, such developments must accommodate themselves to the actual supply of capital and credit available." Rather the amount of capital and credit available should be adjusted to suit the expansion of the rate of production. That, this reviewer thinks, is a fact well-grasped in this country, even by a Conservative Chancellor. Indeed, the criticism should be rather the other way. Power of consumption in this country has over-reached the power to produce. The author is also particularly sensible in his discussion of imports and exports. He points out very clearly that a nation which persistently has what is called a " favourable balance of trade " must in fact be impoverishing itself by sending out of the country more of the goods it produces than it imports of the goods other countries produce ; and he clearly favours a system by which when a country, by this means, builds up enormous credits and refuses to allow them to be discharged by imports, the credits should automatically be cancelled at the expiry of some fixed period.

The latter part of the book is devoted to the discussion of the means of regulating credit in order to maintain a stable price level for full employment and to the discussion of the human factor, including the tendency towards restrictive practices in non-expanding industries like railways, ports and coal-mining. To this reviewer the discussion seems over-simplified. Can, for example, a Government pledged to maintain full employment, ever exercise complete control of the money in circulation and the purchasing power of money when free negotiations between employers and unions can raise wage-rates ? Is it really possible to achieve so exact a balance that the purchasing power of money remains stable without unemployment becoming serious ? Then who really makes the choice as to how much of the national output shall be devoted to " capital " works, those works that increase future output ? Quite clearly that nation which habitually expends the largest portion of its output on capital works will the most rapidly enrich itself. But is it politically possible for a democratic government to fix the figure ; or is it in reality settled by the amount the people are willing to save ? It does not seem beyond a possibility that to bring about expansion there must also be inflation. Nevertheless, there is a great deal of good sense in what the author has to say ; and that good sense is clearly expressed, not in a financier's jargon, but in language which anyone can understand. The book is well worth reading for its own sake ; and it is also stimulative to thought.

Civil Engineering Design : Notes and Sketches. By T. W. Barber, revised by R. Hammond. London : The Technical Press, Ltd., 1, Justice Walk, Lawrence Street, S.W.3. Price 25s.—This book dates, originally, from 1915 and comprises sketches of representative machines, materials and methods employed in civil engineering, accompanied by brief descriptions. The sketches are classified and, generally, are placed on each right-hand page with brief notes relating to them on the left-hand page.

The present revised edition is the first post-war one. It contains additional sketches and some new sections, e.g. on excavating machinery and concrete mixing and placing equipment. Nevertheless, civil engineering practice of the 1915 era is still evident in its contents, and it could hardly be said that a comprehensive collection of basic information relating to modern contemporary practice is given. For example, the section on dams does not mention the basic classifications of gravity, buttress and arch dams in concrete, and earth and rockfill dams. In the section on staging and falsework there is no mention of tubular steel scaffolding ; and more emphasis is given to cast iron than to welded steel. Similar criticism could readily be made of other sections of the book. We rather doubt, however, that the relative complexity of present-day civil engineering practice lends itself to such a single presentation as the book attempts. The book, however, should remain useful, as previous editions were, to engineers in out-of-the-way places or those wishing to refresh their memories about certain aspects of design. A useful addition is a bibliography of civil engineering works published since 1945.

Modern Surveying for Civil Engineers. Second edition. By H. F. Birchal. London : Chapman and Hall, Ltd., 37, Essex Street, W.C.2. Price 50s.—It is pointed out in this volume that the practice of surveying has not changed to any extent during the period of twenty years since the first edition was published, but considerable progress has been made in aerial surveying and with some surveying instruments. The new edition, therefore, contains much new data on modern surveying instruments and on modern practice in aerial surveying. As may be observed from the title, the needs of the civil engineer are specifically catered for in this volume, and after opening chapters on basic principles and instruments, for levelling, angular measurement and similar subjects, there are chapters on problems such as surveys for tunnels and harbours.

Plastics Tooling. By Malcolm W. Riley. London : Chapman and Hall, 37, Essex Street, W.C.2. Price 20s.—This short and conveniently small book sets out to present in easily understandable language the present state of the art of making tools from plastics. The author discusses the properties and prospects of three thermosetting plastics—epoxy, phenolic, and polyester resins—with diminishing optimism, and one thermoplastic, ethyl cellulose, the latter only for drop hammer or stamping work. The methods of using these materials to construct tools are covered in sufficient detail to allow a simple example to be undertaken without further research. The advantages of speed of construction, economy in highly skilled labour, ease of repair and modification, corrosion resistance, light weight and low cost are then balanced against the disadvantages of short working life, the need for moulds and possibly ovens in the tool room, limited working temperature, and the requirement in certain cases to take health precautions when processing resins ; the types of application considered are checking, locating and assembly fixtures, metal forming tools, plastic forming tools, and models and prototypes. Experience has not yet established the life expectation of metal working tools, and the author is guarded in mentioning any figure over 30,000 off : he points out that relatively short runs and the frequent use of aluminium below 0·080in thick allow the aircraft industry to make good use of such tools. Tools forming plastics have, apparently, even more limited lives due to the combination of low thermal conductivity and poor resistance to sustained high temperatures on the part of the tool. This booklet, sixth in the Reinhold Pilot Books, should prove worth acquiring by those with a practical interest in toolmaking.

The T.V.A. By Gordon R. Clapp. London : Cambridge University Press, Bentley House, 200, Euston Road, N.W.1. Price 27s. 6d.—This book is published by the Chicago University Press, whose agents in this country are the publishers named in the title. The author has served with the Tennessee Valley Authority since its inception and was for a number of years its chairman. His book does not give technical information on the civil engineering or other works of the T.V.A., but is more concerned with its social and economic effects on the inhabitants of the Tennessee Valley, and with the growth of industry in the area following upon the T.V.A.'s works of conservation, and surveys of natural resources. Undoubtedly the book has been inspired by recent political controversies, in the United States, about the relative merits of publicly or privately owned electricity undertakings. Mr. Clapp's theme can be summed up in a quotation from the book : " Let no one forget that electric service is a public service, no matter who owns and operates the properties that supply and distribute power." The development of the towns and industries within the T.V.A.'s area, during the twenty-one years of its work, are described in the course of the book, and the achievements of increased prosperity and well-being in the area, and how much they owe to the T.V.A.'s policies are demonstrated by various examples.

A Treatise on Surveying. Sixth edition. By Middleton and Chadwick. London : E. F. and N. Spon, Ltd., 15, Bedford Street, Strand, W.C.2. Volume I, revised by B. G. Manton. Price 32s. 6d. Volume II, revised and edited by Professor Fisher Cassie. Price 32s. 6d.—Middleton and Chadwick's book has for many years been a standard work, which has been brought up to date in this edition. The first volume is entitled " Instruments and Basic Technique " and covers the usual first-year syllabus of universities and colleges. It is confined to plane surveys and places emphasis on practical applications. Volume II continues with more advanced studies ; it is entitled " More Advanced Techniques and Modern Developments," and has been completely recast and rewritten by a number of specialist authors. Precise surveying and levelling work is dealt with in some detail, and aerial surveying and engineering surveys for large schemes are explained. There are also chapters on field astronomy, hydrographic surveying and cadastral surveying.

Books Received

Lignes Electriques T.H.T. By H. Carpentier. Paris: Edition Eyrolles, 61, Boulevard Saint-Germain, Paris Ve. Price 4800 francs.

The Foreseeable Future. By Sir George Thomson. London : Cambridge University Press, 200, Euston Road, N.W.1. Price 10s. 6d.

Nomography and Empirical Equations. By Dale S. Davis. London : Chapman and Hall, Ltd., 37, Essex Street, W.C.2. Price 54s.

Some Experiences of Automobile Research

By C. G. WILLIAMS, D.Sc.*

No. I

On Friday, October 7th, the chairman of the Automobile Division of the Institution of Mechanical Engineers presented an address, which we abstract below.

IT has become somewhat traditional for those who receive the honour of being elected chairman of the Automobile Division to present an address based on personal experience in the field of automobile engineering. I do not propose to make mine an exception. It is, in fact, an opportunity not to be missed : that of tracing the pattern of development from one particular standpoint —in my case that of research.

The Research Association of British Motor and Allied Manufacturers had been formed soon after the 1914–18 war. I am glad that the grandchild of that organisation—the Motor Industry Research Association—has, in addition to its other advantages, a title which is less of a mouthful. R.A.B.M.A.M., as it was called for short, was supported by half a dozen motor firms and about the same number of accessory manufacturers. There were undoubtedly some dogged enthusiasts amongst those few firms and a great deal of credit is due to their foresight. The laboratory was constructed in the garden of a large house at Chiswick—not the first or last occasion on which one of the surplus mansions of England has been used for this purpose. The graduate staff consisted of about half a dozen, and the annual expenditure was of the order of £3000–£4000.

R.A.B.M.A.M. was still a small organisation when, in 1931, it became possible to make a fresh start by winding it up and transferring its assets and activities to the Institution of Automobile Engineers (I.A.E.). I will not enter into the various arrangements which made this possible but, for the next four years, work continued at Chiswick with a growing membership and income, so that by 1934 it was possible to boast of a research expenditure of £8000. In 1936 a move was made from Chiswick to bigger and better accommodation at Brentford, Middlesex.

One of the main difficulties which I experienced in arranging the research programme was that of covering a sufficiently wide range of problems—with restricted resources—to maintain the interest of a diverse clientele. I imagine that other industries have a much simpler problem in organising co-operative research because of their concentration on a single material or product. The automobile industry uses a great variety of materials in the construction of the many mechanisms or components which make up the motor-car, and one could only hope that the limited programme at any particular time was regarded, not only as of special benefit to a few firms directly interested, but also to the remainder, as a contribution towards the welfare of the motor industry as a whole.

The programme during the 1930–40 period was very largely based on replies to circularised questionnaires to member firms. It is of interest that the problems which were most frequent and which, therefore, received attention, were related to durability. Insufficient durability or reliability resulted partly from the general increase in speeds, loads and temperatures. In addition, these durability programmes were supported by (1) the large commercial vehicle operators, who were obviously interested, and (2) the manufacturers of accessories, such as brake linings, piston rings, cylinder liners, &c., who were on their mettle competitively to supply the best possible products to the motor manufacturers. Certainly, some of the former were amongst the most ardent supporters of co-operative research in those days, and rendered continued assistance in the supply of special materials and test specimens. It is also probable that durability problems were looked upon as being especially suitable for co-operative research, since they affected the industry as a whole. Other factors more immediately related to the sales appeal of the motor-car, such as appearance and performance, were left to the forces of competition between the manufacturers.

There was, at that time, no demand for work on petrol or diesel fuels and their combustion. This, perhaps, was an unconscious tribute to the efforts of the oil companies, the Co-operative Fuel Research (C.F.R.) in the United States of America, Ricardo and Co., Engineers (1927), Ltd., in the United Kingdom, and the Delft laboratory of the Royal Dutch Shell group in Holland.

One of the most important factors affecting durability, and one which usually increases in severity with speed, is that of temperature, and the I.A.E. did a lot of excellent work on techniques for measuring temperatures, and on the effect of many operating variables on the temperatures reached by various components. Thus, some early studies were made of exhaust valve temperatures, using a radiation pyrometer. Some research already in progress at Manchester University on piston temperatures was extended, through the provision of financial support, to cover work on small high-speed petrol engines. This latter research was exceptionally valuable in showing the effect on piston temperatures of many design variables, such as head thickness, top land depth and clearance, number and width of piston rings, and so on, as well as the effect of the usual engine operating variables.

Throughout the life of R.A.B.M.A.M. and of the I.A.E. Research Department (and, I understand, as part of the programme of M.I.R.A. at the present time), work has been carried out on the effect of temperature on the frictional and wearing characteristics of brake linings and brake drums. The problem of brake-fade, or "glazing," as it was sometimes called, certainly existed twenty-five years ago, and the reports which were then issued showed no inhibitions in referring by name to the relative merits and deficiencies of the various proprietary materials. Much of this work was confined to small machines but it was realised that experiments on a full-size brake were desirable. The flywheel from an ancient engine retrieved from a scrap-heap provided the necessary rotational inertia, the brake drum and flywheel being coupled together, and an electric motor utilised for repeated accelerations, braking torque during decelerations being measured by a torque arm on the anchor plate. This simple piece of equipment did yeoman service and, fortunately, the flywheel never burst, although I am sure it was operated at two or three times its designed speed. It was on this particular machine that a servo-brake was mounted, and the alarming effect of oil and water on braking, using some of the early friction materials, was first studied. Later, a large amount of work was completed on various brake drum materials from the standpoint of their resistance to wear and scoring.

The main durability problem studied at the I.A.E. Research Laboratories was that of cylinder wear. Following its formation in 1931, the I.A.E. Research Committee decided that this was the No. 1 problem facing the motor industry and, later that year, I had the task of preparing a suitable programme. An examination of the literature revealed that most attention appeared to have been devoted to the influence of material hardness, microstructure, &c., and that dilution of the lubricant with petrol on starting was assumed to be a major accelerating factor. There were, however, a host of competing explanations and remedies, and a list of the more important variables which I made at that time totalled twenty-six ; I am sure that list could very easily have been extended. The opportunity was also taken of collecting the experiences of motor manufacturers and large vehicle operators which, while very instructive, all served to multiply the number of variables which might or might not be of importance.

The proposals for an experimental programme which I submitted were based on the use of small single-cylinder engines. It seemed to me that the utilisation of such engines would permit the closer control of lubrication, carburation, and cylinder temperatures, would facilitate handling and measurement, and would cheapen operation and replacement. These arguments were all proved correct by experience, although there was some opposition from those "realists" who pointed out that no motor-car used single-cylinder engines and, therefore, I was departing from practice and my results would be meaningless. This was not the first or the last time that I ran into such arguments, but the plan was accepted and four single-cylinder units installed.

The effect of dilution with petrol being the principal suspect, the first experiments were carried out with the crankcase lubricant diluted with various percentages of kerosene. Much to my surprise, over a very wide range of dilution, covering a 20 to 1 ratio of viscosity, there was practically no change in rate of wear.

The next variable examined was that of reducing the supply of lubricant to the cylinder walls and, fortunately, the roller bearings used on the crankshaft of these single-cylinder units permitted a drastic reduction in the supply of lubricant without causing too much trouble. In fact, the oil supply was reduced to the fantastically small amount of 0·001 gallon per hour without encountering increased cylinder wear under continuous (but not too severe) operating conditions. The possibility that increasing the cylinder wall temperature might give rise to correspondingly increased rates of wear was studied on an air-cooled engine from which it was found that wear, even with scanty lubrication, was no higher at a cylinder wall temperature of 265 deg. Cent (509 deg. Fah.) than at 125 deg. Cent (257 deg. Fah.).

At the time these experiments were performed the results may have appeared discouraging, but they illustrate a point which has, on several occasions, been evident in my experience, and I am sure in that of many

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others, namely, that it is the unexpected result which is often the most revealing and which becomes the turning point in an investigation. In this instance, it was evident that I had not introduced conditions which gave rise to the sort of wear rates experienced in service. There was sufficient reason for believing that some conditions operative when starting an engine from cold gave accelerated wear—but apparently neither dilution nor shortage of lubrication was the main factor. I assumed, therefore, that it was desirable to carry out some cyclic tests. This was, in fact, the first occasion on which I realised that there might be some important factors present under intermittent operating conditions which were absent under continuous operation and, subsequently, the same discovery was made in regard to other engine problems, for example, exhaust valve life, the pro-knock effect of combustion chamber deposits, and so on. These cyclic tests proved that wear could be increased to a startling extent by a delayed warm-up, particularly if associated with a deficiency of lubrication. Low wall temperatures were obviously responsible and continuous operation at such temperatures showed greatly accelerated rates of wear, resulting in the preparation of the graph shown in Fig. 1.

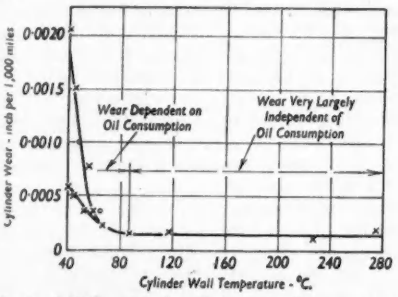


Fig. 1—Cylinder wear in relation to wall temperature

This result was a turning point in the investigation expressing, as it did, the now well accepted influence of low jacket temperature on wear.

It seemed obvious that this increase in wear was associated with the condensation on the cylinder walls of water from the products of combustion. By working out dew points of the products under conditions existing inside the cylinder, it was possible to show that wear increased at a temperature somewhat below the dew point. There were, however, two possible ways in which water could accelerate wear, namely, by " washing-off " the oil film, with consequent abrasion, or by giving rise to corrosion. The pitted and discoloured appearance of piston rings and cylinder walls observed on engines which had been running continuously at low temperatures suggested that corrosion was the more likely explanation.

There seemed to be a number of possible acids which could aggravate the effect of the water of combustion, and some interesting work was carried out with the object of trying to pin-point the culprit. This entailed running engines on some rather unusual fuels and atmospheres. Thus, one of the possibilities—organic acids—requires a carbon-containing fuel and therefore, to eliminate this possibility, tests were carried out in which an engine was operated on hydrogen as a fuel. These experiments, in which I acquired a healthy respect for the explosive properties of hydrogen, eliminated the possible influence not only of organic acids, but also of fuel sulphur, and the results showed a very considerable reduction in wear, although not a total elimination. Operation of an engine on hydrogen also revealed another interesting phenomenon—the remarkable absence of any apparent deterioration in the cleanliness of pistons or lubricant—the latter retaining its pristine golden hues. This was my introduction to the all-important influence of combustion products from normal fuels on the degradation of lubricants.

Nitric acid, formed by the union of atmospheric oxygen and nitrogen during the explosion, was another suspect, and engine tests were therefore carried out using an artificial atmosphere free from nitrogen, a mixture of carbon dioxide and oxygen being substituted. These tests gave most unexpected results, wear being increased very considerably. This led to the supposition, subsequently confirmed by other experiments, that carbon dioxide in the form of carbonic acid had an important corrosive effect. It was not possible to pursue this interesting but rather expensive line of research, but it all tended to show that corrosion was not due simply to one acidic product, but probably to a combination.

It is of interest that, within the last few years, an entirely different technique for measuring the concentration of acidic products has been used at Thornton research centre. In this instance a probe, consisting of copper and zinc electrodes separated by mica, was inserted into the combustion chamber. Under low temperature conditions transient electromotive forces were generated of a magnitude similar to that of a voltaic cell, acid condensation bridging the gap between the two metals.

The publication in 1934 and 1935 of the I.A.E. work caused very considerable interest and not a little controversy. The experiments had been carried out with very limited resources and I imagine that, up to this point, no more than £5000 had been spent in all. Much of the work was exploratory, and I doubt whether some of it would have survived the critical eye of a professional statistician had I thought, at that time, of using such an expert. The whole investigation seemed, however, to " hang together " and the motor industry was not long in taking some action, the first being the more widespread adoption of thermostatic control of cooling water temperature. I obtained the co-operation of certain firms in making experimental piston rings and cylinder liners of relatively non-corrodible materials, for example, austenitic cast iron, and some of the first experiments on chromium-plated piston rings were undertaken at that time. It seemed a simple and logical deduction, also, that one might attempt to neutralise these acidic products by using an alkaline lubricating oil, and I approached one or two oil companies at that time to ask for their ideas on oil-soluble additives, but little or nothing came from this approach. It would seem that the opportunity was then missed of anticipating, by more than ten years, the development of acid-neutralising lubricants which have been so widely extended and marketed since the war.

The cylinder wear research was continued until the outbreak of the 1939–45 war, and a very wide range of variables studied, which there is no need to discuss in an address of this kind. Suffice it to mention that they covered a range of piston, ring and engine design variables, and some fuel and oil factors. In regard to the latter, interest was being shown in the use of lubricants of lower viscosity, that is of the S.A.E. 10W variety. Engine tests under continuous conditions showed that wear tended to be somewhat higher with the lubricants of lower viscosity, more especially under conditions of corrosive wear. This was only half the story, however, since it might be assumed that, under normal starting conditions, the " thinner " lubricant would get to the cylinder surfaces more quickly and exercise its protecting effect when needed most. To study the spread of an oil film between the pistons and cylinders after starting from cold, a technique was developed of measuring the electrical resistance between piston and cylinder wall. This electrical resistance was considerably greater when an oil film was present than when the rubbing surfaces were dry with good metal contact. These experiments certainly confirmed the beneficial effects of low-viscosity lubricants, the time taken to establish an oil

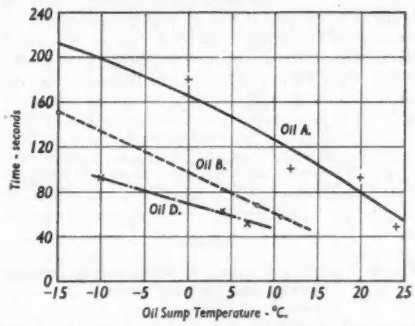


Fig. 2—Time taken to establish oil film with oils of different viscosities

film with oils of three viscosities at varying temperatures being shown in Fig. 2.

While the problem of cylinder wear is now much less serious than formerly, it is still frequent enough to cause the continued interest of oil companies in developing lubricants for its reduction to negligible proportions. Such research has been carried out at Thornton—and here I am taking the liberty of advancing several years. One technique which has been used would not have been possible in the 1930s—the use of radioactive tracers. A normal piston ring, made radioactive by being placed in the pile at Harwell, is fitted to the test engine and metal worn from it is carried into the sump by the circulation of oil. The oil is circulated through an oil-counting cell which picks up the radiation from the radioactive particles in the oil. Since the activity of the oil is directly proportional to the mass of active material which it contains, it is possible to derive a figure for the metal worn from the piston ring and, in fact, for a wear-time graph to

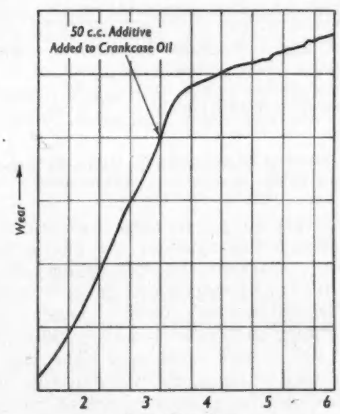


Fig. 3—Reduction of wear with lubricating oil additive (radioactive piston ring method)

be automatically plotted. The great advantages of such a technique are that it permits the study of wear without dismantling the engine, and that measurement can be made with great rapidity. Fig. 3 shows a record made with a diesel engine unit in which a radioactive chromium-plated piston ring had been

fitted. The reduction in wear with an anti-wear additive is shown, the effect not being immediate. Another wear-time chart, showing how the changing wear rate during warm-up can be followed, is given in Fig. 4.

Piston rings—their behaviour and misbehaviour—seemed to play a large part in my thinking during the 1930–40 period, and one of the problems then tackled was that of excessive blow-by at high engine speeds. This blow-

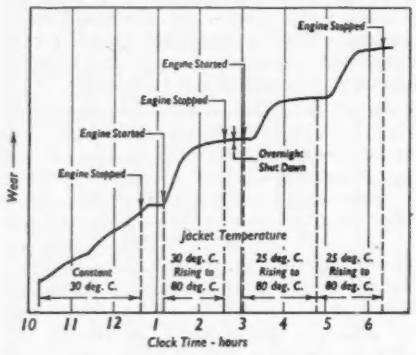
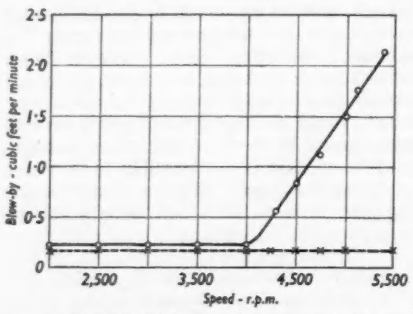

Engine Stopped
Engine Started
Engine Stopped
Engine Started
Engine Stopped
Overnight Shut Down
Wear
Jacket Temperature
Constant 30 deg. C.
30 deg. C. Rising to 80 deg. C.
25 deg. C. Rising to 80 deg. C.
25 deg. C. Rising to 80 deg. C.
10 11 12 1 2 3 4 5 6
Clock Time - hours

Fig. 4—Variation of wear rate during normal running, starting and warm-up periods

by could increase suddenly at a critical speed, Fig. 5 showing a typical set of results. Operation of the engine under these critical conditions could sometimes cause breakage of the piston rings into small fragments, so that high stresses were obviously involved which were generally attributed to a vibrational phenomenon called "flutter." An engine was fitted with a gasometer coupled to the crankcase for measuring blow-by and a large number of variables studied. This work showed that blow-by could be reduced, or the critical speed increased, in a number of ways, for example, by reducing ring side clearance, increasing radial pressure, or reducing ring width. Resulting from these



——— Ring width 0·093in, radial pressure 11·8 lb per square inch, radial thickness D/29.
- - - - - - Ring width 0·062in, radial pressure 12·2 lb per square inch, radial thickness D/29.

Fig. 5—Effect of engine speed on "blow-by" showing sudden increase at a critical speed

tests a theory was put forward to explain ring flutter which was based on the inertia, gas pressure and frictional forces acting on the piston ring in the region of top dead centre.

Another durability problem which was causing some concern early in the 1930s was the wear of exhaust valve seats. This was in the early days of hardened valve inserts, and it is not surprising, in the light of present information, that sinkage of a valve into its seat sometimes occurred with alarming rapidity. A manufacturer presented the I.A.E. laboratory with a piece of apparatus in which the problem could be studied and, on the principle that I could not afford to look a gift horse in the mouth, this apparatus was used and gave some useful leads. It was essentially an overhead valve cylinder head, in which the exhaust valve was operated in the normal manner. The place of the cylinder barrel was taken by a gas-heated muffle so that the exhaust valve was exposed to the radiant heat from the muffle, and also to the products of combustion. This work, and subsequent experiments carried out on actual engines, showed that the suspected bad influence of weak fuel-air mixtures was due, not to increased valve temperatures with such mixtures, but to the presence of oxygen in the exhaust. It was apparent that high temperature oxidation of the valve seat materials was taking place. Much work was carried out on many variables, but most attention was devoted to a wide range of experiments on various ferrous and non-ferrous valve seat insert materials tested under these oxidising conditions.

About 1937 an extramural research was started at Ricardo and Co., Engineers (1927), Ltd., Shoreham-by-Sea, Sussex. This began for me a happy association with the firm which continues to the present day. While they had already carried out work for the former research association, the research which I was instrumental in starting related to factors affecting lubricating oil consumption. I have always felt that this was an excellent piece of research which, perhaps, has not received the attention it deserves. The work was undertaken on a single-cylinder engine with accurate methods of measuring oil consumption, and a very wide range of variables was examined. The work showed quantitatively the importance of many design features, such as piston skirt clearance, top land clearance, piston ring side clearance, and piston ring gap. The latter, for example, was found to be of unsuspected importance. Other studies related to the effect of piston ring pressure, ring width, oil viscosity, and so on. Subsequently, some work was carried out on the lubricating oil consumption of diesel engines, the problem being to study the wide variation in oil consumption observed between compression ignition engines of the direct injection and indirect injection types. Other things being equal, the latter engine showed a threefold higher oil consumption. The difference was found to be due to the asymmetrical temperature gradient with this type of engine, which produced distortion, and to the more intense air turbulence during combustion. A modified version of the separate chamber arrangement, designed to give a more uniform temperature over the piston and to shield the cylinder liner from the direct blast of hot gases, resulted in a decrease in oil consumption.

Still another durability investigation concerned gears. Many different steels and methods of finishing were in common use for gears in motor vehicles and, in 1935, it was decided to ascertain the influence of such factors and also to study gear lubrication. It happened that, at that particular time, I saw in the Delft laboratories a small machine of the power circulating or four square type. This was being used for making short duration tests on lubricants and one of them was loaned by Delft to the I.A.E. Research Laboratories. Considerable preliminary work carried out on this machine showed that, for endurance testing of hardened gears and for rating additive lubricants, a much stronger machine would be required and, therefore, a new design was prepared employing the same principle, but with many refinements. For a few years the story of this machine was very largely one of development and, in fact, development continues at the present time. The object was to obtain repeatable scuffing failures and, by 1938, useful results were beginning to appear, and a long programme of studies on gear materials, gear finishes, and lubricant additives was under way.

During the 1939–45 war this machine was installed in a number of laboratories as the only practical method then available for measuring the characteristics of lubricants under actual gear conditions. The machine showed, in fact, some correlation with full-scale tests on a Rolls-Royce "Merlin" reduction gearbox and, after the war, a correlation programme amongst various users of the machine, in order to standardise a test method, was organised by the Institute of Petroleum. While the machine is not entirely suitable for rating oils for hypoid gears, it has been very satisfactory for straight, spur and helical gears. The original design speed was 2000 r.p.m., but, since 1945, its speed has been increased to 4000 r.p.m. and at Thornton we have recently increased its speed to as high as 12,000 r.p.m.

In the early days of R.A.B.M.A.M., a large amount of work was completed on the fatigue of laminated springs. The problem of fatigue entered the I.A.E. Research Laboratories in 1936, because fatigue failures had also become rather serious on diesel engine crankshafts, failures in bending being experienced in service to a somewhat disturbing extent. A number of machines were designed and constructed for testing full-sized crankshafts under reversed bending, and a series of investigations started which, I understand, are still under way at the Motor Industry Research Association. Considerable information was obtained on the influence of crankshaft material and on certain features of design, but the most revealing information for me came from studies of the influence of various surface treatments. In particular, chromium-plating reduced the fatigue strength very considerably, an effect which was attributed to tensile stresses existing in the chromium-plating. On the other hand, nitriding showed a considerably enhanced fatigue strength, in this case due to compressive stresses. At about this time the Engineering Department of the National Physical Laboratory had developed a machine for studying fatigue under conditions of combined bending and torsion, and a certain amount of collaboration ensued, especially in regard to cast materials which were becoming widely used for crankshafts.

I hope what I have said so far has given an idea of the kind of studies with which I was closely associated at R.A.B.M.A.M. and at the I.A.E. Research Laboratories. The latter had expanded and the membership had grown to the extent of warranting an annual expenditure of approximately £20,000 when the 1939–45 war started. The war caused a drastic review of the programme and the introduction of certain new items—for example, an examination of alternative fuels, including gas producers for road vehicles. These subjects became the responsibility of my successor for, in 1940, I moved to Thornton, where the Shell Petroleum Company had decided to construct a new laboratory for the study of aviation fuels and lubricants. The staff then numbered one or two, and the problem of staffing and equipping a laboratory under wartime conditions would certainly provide material for another and quite different story. By the end of hostilities, the staff of the Thornton Aero Engine Laboratory numbered 275, and the expansion of activities in directions other than aviation had already begun; its staff now numbers nearly 900.

(To be concluded)

Baudouin Lock at the Port of Antwerp

The new lock recently completed at Antwerp has a useful length of 1180ft, a width of 147ft and a depth of water of 51ft at high water. It is of reinforced concrete construction and has four welded steel caisson gates. Heads of up to 5m on the dock side and 4m on the river side will be experienced.

THE docks at Antwerp form an impounded system connected with the River Schelde, or Escaut, as it is also known, by five entrance locks. At the northern end of the port the Kruisschans lock provides the largest entrance, which leads into the Hansa basin, and hence to other parts of the dock system. The remaining entrance locks, whose principal dimensions are listed in the table, are situated some distance further up the river. Duplication of the Kruisschans entrance was decided upon some years ago, due to increasing traffic at the port, and a new lock—Baudouin lock—is now approaching completion after five years of constructional work at this site, to provide the port's sixth river entrance.

Locks Serving the Port of Antwerp

Name of lock	Length	Width	Depth at high tide
	Metres	Metres	Metres
Kruisschans	270	35	14·98
Royers	180	22	11·08
Kattendijck	110	24·8	7·73
Bonaparte	—	17·4	7·16
Zuiderdok	75	13	6·05
Baudouin :			
Between outer gates ..	360	45	15·49
Between inner gates ..	315	45	15·49

The new lock is of imposing dimensions (its length is 1180ft, its width 147ft, and the depth of water at high tide is 51ft), and it is thought that the only larger locks in Europe are the ones at Ymuiden at the entrance of the North Sea canal in the Netherlands. Its layout in relation to the Kruisschans lock is shown in the diagram, from which it will be seen that the two lock centre lines are 250m apart ; the approach walls of the new lock are shown and may be compared with the earlier layout of the Kruisschans lock.

Baudouin lock is, generally, of reinforced concrete construction. It has two pairs of caisson gates, the recesses for which are also shown in the illustration. Its dimensions were chosen so that four 10,000-ton ships could be accommodated in it simultaneously. At the site of the lock the ground level was at about +7·5m,* and there was fine, compact sand down to −25m in the clay below it ; a peat layer 1m to 1·5m thick was found at the −1m level. Generally, the water table was at about +2·5m ; excavation extended to a depth of some 22m below ground level.

Excavation for the lock totalled about 1,600,000 cubic metres, and was done by draglines of up to 5 cubic metres bucket capacity. Ground water was lowered by submersible pumps placed in twenty-eight wells sunk to the clay at various points round the lock. Each pump dealt with 9000 litres of water per hour and the water table was lowered more than 17m. Water from above the peat layer was drained away by normal methods. The banks of the excavation stood at 1 : 1 slopes throughout the work.

The cross section of the lock illustrated shows the somewhat slender proportions of the reinforced concrete walls, which are not buttressed ; the two walls are structurally independent, and each one has been designed to retain the sand fill behind it and is built in ten 21·5m sections separated by expansion joints. A steel-sheet-piled cut-off has been built under the toe of each wall, to reduce seepage. Steel-strip water stops have been built into the principal construction joints of the wall. The lock floor consists of concrete slabs 10m square and 1m in thickness, laid on a permeable layer of sand and gravel 0·6m in thickness. Drainage walls have been left so that hydrostatic pressure will not build up under the slabs. The design envisages that it will never be necessary to empty the lock.

In the neighbourhood of the gate recesses and sills the walls and floor of the lock have been built more substantially. The maximum thickness of concrete under the gate sills is 4m, and at and near the gate recesses the walls are of gravity section.

The total quantities of concrete and steel reinforcing needed to complete the lock were, respectively, 340,000 cubic metres and 9000 tons. Concrete was mixed in four 1250-litre mixers after weigh-batching and a somewhat elaborate plant was needed for stocking and handling aggregates and cement.

Caisson Gates

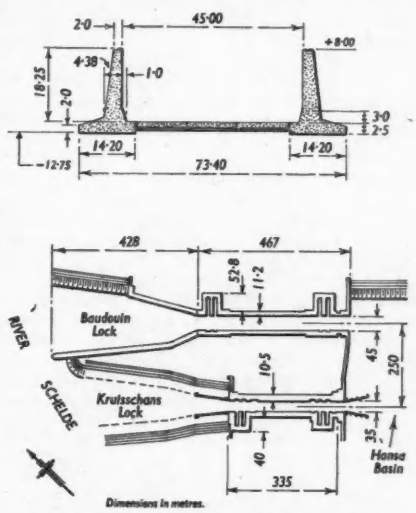
There are four caisson gates in the lock, each with its own gate recess, which can be sealed and dewatered. Two of the gates are intended as stand-bys. Each gate is of welded mild steel construction and weighs 840 tons. It will withstand the head on either side, its overall dimensions being a length of 47m, a width of 8·58m, and a height of 18·8m from the rolling ways. The downstream gates were modified after the 1953 storm surge, however, and they have a height of 19·15m.

Each gate has six decks arranged with a ballast tank, which is divided into twenty-four watertight compartments, between the third and fourth decks. Compressed air for emptying the tank is brought from a compressor installation on the quayside ; there are no pumps or motors in the gate itself.

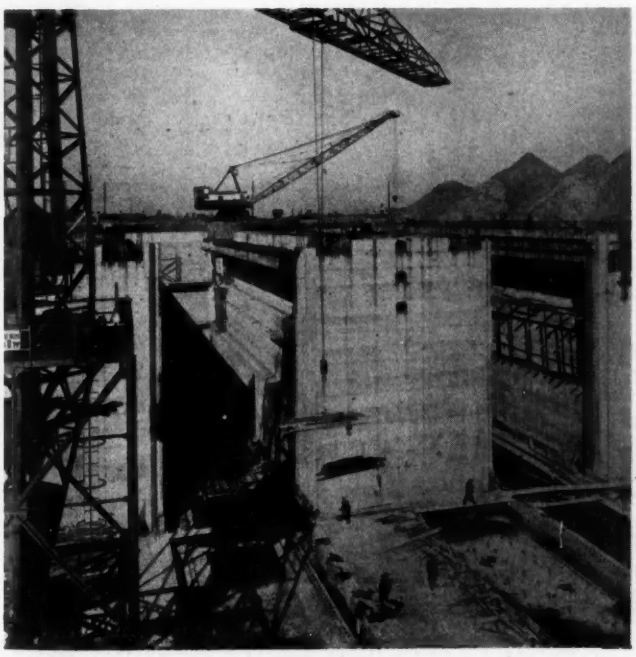
The gate is carried on wheels, at sill level under the outer end of the gate, and at top water level at its inner end.

These wheels are of steel and are 1·35m in diameter, and run on steel ways. The ways in the gate groove are spaced 6·14m apart, and those mounted at the sides of the gate recess, near the top of the gate, are 10m apart. The gate has a bogie underneath it near its outer end, from which the wheels bear on to the ways in the gate groove, and an upper bogie carried on a bracket at the top of the gate, at its inner end. The wheels of this latter bogie run on the ways in the gate recess.

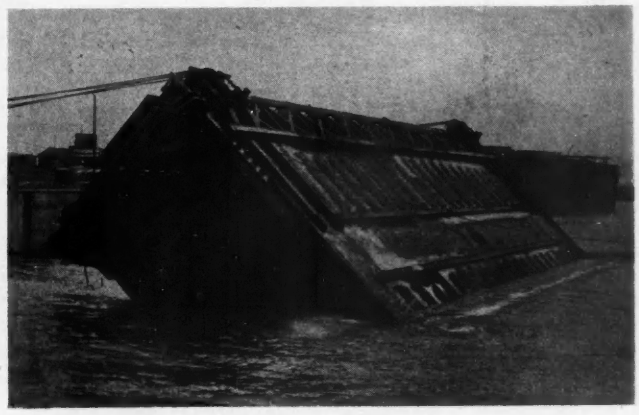
The lower bogie is housed under a dome-shaped recess in the gate, which can be dewatered with compressed air for maintenance of the bogies ; also, the gate can be lifted clear of this bogie by altering its " trim " in the ballast tank. When the gate is to be inspected in the dry, in its gate recess, it can be taken off the bogies and carried by brackets fastened to it, and to appropriate bearing attachments in the recess. Maintenance of the rolling ways in the gate groove is to be carried out, without inter-



Typical cross section and plan of Baudouin lock



Construction of the inner gate grooves and gate recesses is here shown in progress



One of the caisson gates being uprighted after it had been floated down the Schelde from the maker's yard

* The zero datum is the ordinary spring tide low water mark.

fering with traffic, when the corresponding gate recess is dewatered. Small " U "-shaped caissons will be placed to form a tunnel, covering the way, and connected through the cofferdam sealing the gate recess. Thus, compressed air will not be needed.

The gates are cable-operated at a speed of 0·25m per second, so that it takes three minutes to open or close a gate. There is a cable tunnel passing under the sill of the lock. The gate recesses are each 51m long, 8·6m wide at the lock and 10·5m wide further in. Each pair of recesses is separated by a concrete wall 12m thick at its base, with a pump chamber in it for housing the centrifugal pumps serving the recesses. The culverts controlling the lock water level are also built into the relatively massive parts of the lock near each pair of gates. There is a control building for each pair of gates, where the culvert sluice valves are also controlled.

The culverts are each 5m by 5·5m in size, and there are two at each end, one on each side of the lock. They are each controlled by a pair of sluice valves each 2·25m by 5·61m in size. A central column is built into the culvert at this point. Each valve can be isolated for maintenance. The culverts each discharge into the lock through a chamber 30m long with six openings, each 4m by 2m, to the lock. The invert of the lock is lowered by 1·5m over the length where these openings are situated, as shown in the illustration below. This layout was tested on a hydraulic model and gives the least turbulence and sideway forces on ships in the lock, during filling and emptying.

The highest tides in the Schelde at Antwerp reach a level of about +8m, and the lowest tides reach −1m. The dock level is kept at +4m. Thus, the heads on the lock gates may vary from 5m on the dock side to 4m on the river side. For the worst condition (i.e. 5m head) the lock can be filled in fifteen minutes. There are also twin culverts 500m in length connecting the Hansa basin with the river approach of the lock.

The approach channel to the lock is 560m long and has walls where ships waiting to use the lock can be moored. It is dredged to the −10m level, and protected from scour for a distance of 20m from the lock by concrete slabs and for a further 60m by fascines, as shown in the illustration below. Other work has included the construction of a riveted steel lifting bridge, also shown in the background of the same illustration, an extension in the Hansa basin and some road works.

Excavation of the approach channel was completed at the end of July. The lock has been built under the direction of the Belgian Administration des Travaux Publics et de la Reconstruction at a cost of just over £6,000,000.

The river end of Baudouin lock, before flooding. Fascine work in the river entrance is shown in the foreground. The twin culvert from Hansa basin is on the extreme right. The two outer gate recesses may also be noted, and the arrangement of the filling and emptying culverts round them is clearly shown

Five Centuries of British Timekeeping

THE recent timekeeping exhibition, held in London, as its name, " Five Centuries of British Timekeeping " implied, purported to show the development of British horology during the past 500 years, and to show how many of the important technical advances in the construction of clock and watch mechanism have been the work of British inventors. It also marked the successful completion of the first twenty-five years of clock manufacture since the revival of the industry in this country in 1930, a daring step by a few manufacturers that has produced a valuable and prosperous organisation.

The exhibition was held in Goldsmiths Hall, Foster Lane, London, E.C.2, lent by the Worshipful Company of Goldsmiths, from October 3rd to 8th, and was divided into two main sections. One of these consisted of a collection of magnificent antique specimens of clocks and watches, and included examples of the work of famous makers during the period before the British industry was eclipsed by foreign manufacturers. The other section was made up of the products of present-day makers, and showed what has been achieved since the revival of horology in this country.

In the historical section the earliest form of mechanical timekeeper was exemplified by a tower clock movement formerly at Cassiobury Park, Hertfordshire. Made almost entirely of hand-forged wrought iron, this clock is typical of early tower clocks, and although not itself amongst the oldest in existence, it was shown because it retains the " verge-and-foliot " escapement that was universally used before the introduction of the pendulum about the middle of the seventeenth century. Most clocks were soon converted to pendulum control, but this example remains in its original condition.

The clock, which has a " birdcage " frame, made up of iron bars riveted and wedged together, was shown in going order, and the action of the " foliot," which consists of two weighted arms that operate the verge pallets, and so release the teeth of the escape wheel, gave a good idea of the somewhat crude principles on which early escapements were based. Clocks of this kind often varied as much as an hour in the twenty-four. The striking mechanism of the Cassiobury clock also remains in its original form, and it was interesting to observe how closely the locking plate control, which governs the number of blows struck at each hour, resembles that used on present-day tower clocks. There cannot be many mechanical devices which have remained practically unaltered for over 400 years.

The earliest domestic clocks were largely small copies of tower clocks, and so they usually show marked resemblances in design. The result was the type of clock known as the " lantern," and a fine specimen in the exhibition, a small lantern clock by the famous Thomas Tompion, showed such similarities very well, the going and striking trains being mounted end to end in the frame and the train bars wedged in place. This same form of construction was probably originally possessed by the fine wall clock loaned by Her Majesty the Queen, and reputed to have been given to Anne Boleyn by King Henry VIII. As, however, its original movement was replaced by another in the nineteenth century, its historic value is largely lost.

Another early form of domestic timekeeper was the table clock, which usually stood in the centre of a table, with the dial horizontal on the top of the case. A particularly fine example of a clock of this kind exhibited is shown in Fig. 1.

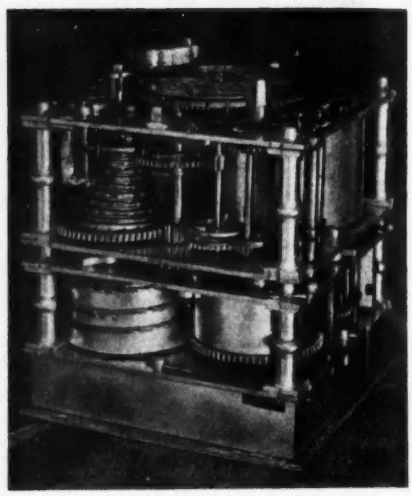


Fig. 1—Movement of the Fromanteel-East table clock, shown inverted with striking work on top, time and chiming train underneath

It is inscribed with the joint names " A. Fromanteel " and " E. East," and is of very unusual construction, the mechanism being divided into two sections. The upper part of the frame contains the going, or timekeeping, train, and the chiming train, the former being controlled by a verge escapement and a balance and spring, the latter being almost certainly a later addition. The lower compartment of the frame contains the striking train, the hours being sounded on the elaborate system known as " grand sonnerie." The escapement is very oddly placed in the centre of the movement.

The elaborate ornamentation of the case is a notable feature of this clock, and is beautifully executed, but vandalistic hands have caused some damage, for the movement is scratched and dented and the minute hand is broken off, leaving only a mere stump at the centre.

The next stage in the development of the domestic clock was the appearance of the bracket and long-case clocks; the exhibition contained some fine examples of both forms. The finest of the bracket clocks was, undoubtedly, the famous " Tulip " Tompion, so called because of the finials resembling tulips at the corners of the top of the case. The movement of this clock is a remarkably fine piece of work, even for such a master as Tompion, and is constructed to sound " grand sonnerie " or, in other words, to strike the last hour after the chiming of each quarter.

Another bracket clock shown had a metal case, a very unusual feature. It was made by William Webster, a notable maker, who was apprenticed to Tompion, and it dates from about 1730. The movement, which is a fine piece of workmanship,

shows traces of Tompion's influence. Yet another bracket clock with a velvet dial was included, its maker being the famous Joseph Knibb. The striking of this clock is on a system rarely used, and known as "Roman striking." In this the hour strokes representing hours up to IIII are sounded on a small bell and those for V or over on a larger one. To give an example of this, VII would be sounded as one blow on the larger bell, followed by two blows on the smaller. The object of the arrangement was to reduce the number of blows struck, and so to increase the length of run of the striking train for each winding, but the method never became popular.

The work of George Graham, Tompion's most famous associate, was represented by yet another bracket clock in a walnut case. It is a distinctly fine example and was apparently made for use in a bedroom, for it has a special silent escapement, and is also provided with repeating mechanism which enables the time to the last quarter of an hour to be ascertained in the dark by the pulling of a cord projecting from the side of the case. This "repeating work" was a development of the British invention of "rack" striking, a mechanism in which the number of blows struck was determined by the position of the hour hand. This improvement is now standard on all domestic striking clocks, and repeating work, which could only be applied to rack striking clocks, became very popular, only falling into disuse with the coming of the modern luminous dial.

Other exhibits in this section included a decorative clock with numerals of the kind used in Turkey. Made by Markwick Markham, it is an early example of a clock made for export. Another Tompion clock, one of the smallest made by him, was probably one of the first travelling clocks, for its case is robustly made in steel and it has no striking, though there is an alarm train.

To round off this section there was a novel "Congreve" clock, in which the release of the escapement is controlled by a ball which rolls down a zigzag groove in a tilted metal plate. As soon as the ball arrives at the end of its journey it trips a lever, releases the escapement, and has its plate tilted the other way. This causes it to start off on a journey in the opposite direction down the groove, at the end of which the process is repeated. As a timekeeper the design was not a success, for the duration of the travel of the ball was affected by variations in friction, but the clock was shown as an oddity in timekeeping mechanism.

The most notable of the long-case clocks to be

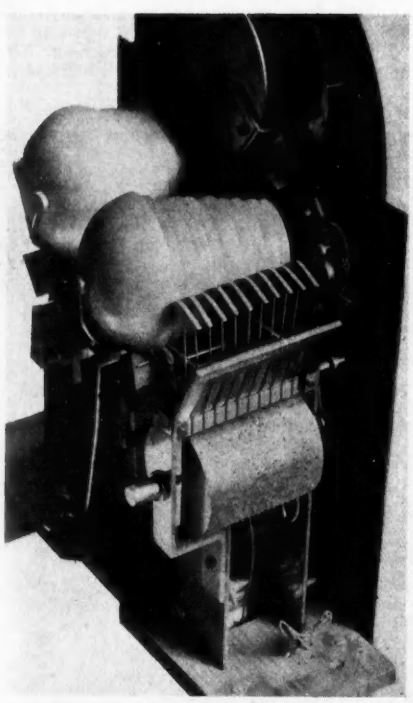


Fig. 2—Vickery clock mechanism with dead beat escapement and an invar pendulum of seconds length

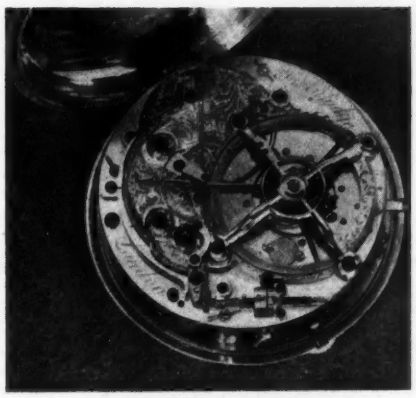


Fig. 3—Queen Charlotte lever watch

shown was the fine specimen made for King William III by Tompion. In design and craftsmanship both case and mechanism are quite outstanding. The clock goes for three months with one winding, is fitted with the recoil escapement, which, invented by Clement, a famous English horologist, enabled the pendulum to give really good results, and has a perpetual calendar attachment which even corrects the date shown for leap year. Originally at Hampton Court, the clock seems to have passed out of Royal ownership, and was taken to America in 1928. Now it has returned to this country permanently and is in the possession of Mr. J. S. Sykes, by whom it was loaned to the exhibition.

In the opposite corner of the exhibition hall was another long-case clock of very rare form. It is a "night clock" made by Edward East and has a perforated rotating dial, the figures on which are illuminated from behind by a lamp. There are, of course, no hands, but it is quite easy to read the hours and quarters by the light of the concealed lamp. The movement is a timepiece of simple design and the whole clock is an interesting example of a timekeeper designed for a special purpose and so a forerunner of the many diverse types of special clocks in use to-day.

The third of the four long-case clocks shown is also of novel form, being a twenty-four-hour "day and night" clock, made by John Ellicott, another famous maker. Its main dial is divided into twenty-four hours instead of the usual twelve, and the gearing which drives the hands, the "motion work," as horologists call it, has a 24 to 1 ratio to give the appropriate movement to the hour hand. In the centre of the dial is a golden segment, which expands and contracts in step with the seasons to give the times of sunrise and sunset. This is operated by a "year" wheel driven through 365 to 1 gearing from the motion work. A further detail is the calendar dial, which appears further down on the case, and above the door in the trunk portion. This indicates the day of the month by the movement of a hand round an elaborately engraved divided dial. A small hand on the same dial shows the equation of time.

The final exhibit (Fig 2) in the long-case section is fairly modern. It is a very fine clock made by Thomas Vickery, a maker who died only a few years ago. In designing and constructing the clock Mr. Vickery set out to demonstrate that the skill and craftsmanship of former days were not dead, and the clock he made amply proves this. Externally it is of simple, almost standard, long-case form, but the mechanism, every detail of which was made by Mr. Vickery, is extremely complex. The clock has dead-beat escapement and an invar pendulum of seconds length. It chimes the quarters on a set of bells and can be adjusted to sound either the Westminster or Whittington chimes. In making this chiming and striking mechanism Mr. Vickery achieved the remarkable feat of obtaining the whole four quarters and the striking from one train of wheels, a thing that horologists considered impossible. A third train of wheels operates a tune-playing barrel which has seven tunes, one for each day of the week. These tunes are changed automatically each midnight and their notes are sounded on a separate set of bells. Two small dials, set above the main dial, give the times of sunrise and sunset in hours and minutes, and above them, in the arch of the dial, is a special dial, which indicates the moon phases and the position of the principal constellations. Between the figure XII on the main dial and the dial centre is an equation-of-time dial, operated by a kidney cam that is, in turn, driven by bevel and worm gearing from the motion work of the hands on the main dial.

Not content with this, Mr. Vickery fitted a perpetual calendar in the circle of the main dial above the figure VI. This shows the day of the week and the date on two small dials and the month of the year through an aperture between them. All corrections are made automatically, including that required for leap year.

Even the fine case, in oak and pollard oak, was made by Mr. Vickery, and the clock is rightly regarded as one of the masterpieces of horology.

The watch exhibits included some notable examples, the most important being the "Queen Charlotte Lever Watch," sometimes described as the most important watch in the world. This watch (Fig. 3) was made by Thomas Mudge, the inventor of the lever escapement, and it was the first to have this now universal escapement. It may therefore be justly claimed that it is the prototype of all the millions of lever clocks and watches that are now at work. It was the lever escapement that gave horology the most important improvement in timekeeping for escapements with balances and made possible, not only a reliable watch, but also such industrial clocks as time switches, gas control clocks and a multitude of other special timekeepers.

Another lever watch by Josiah Emery demonstrates some detail improvements in the construction of the escapement which have become standard practice. A lever clock, made by Thomas Mudge, with a large-size lever escapement, was also included in this section.

Other watches shown included an early stopwatch, an equation watch by Ellicott, a watch showing mean and sidereal time, by Margetts, and a magnificent eight-day repeating watch with Arnold's chronometer-detent escapement, made by Alexander Watkins for the great 1851 exhibition (Fig. 4). Other watches in the section, such as that given by King Charles II to Miss Jane Lane to mark her assistance in his escape after the battle of Worcester, the skull watch owned by Mary Queen of Scots, the large watch carried by Captain Bligh on the "Bounty," and several other examples, had an interest that was more historical than technical.

If a word of criticism may be said concerning this antiquarian section of the exhibition, it is that there does not seem to have been any attempt to illustrate the inventions of British horologists in a full manner. The exhibits were good, so far as they went, but a few models, illustrating such far-reaching inventions as the

Fig 4—Watkins eight-day repeating watch made for the Great Exhibition of 1851

cylinder and lever escapements for watches, the recoil and dead-beat escapements for clocks, and such other devices as maintaining power, rack striking, and so on, would have been helpful to visitors. There was also the need for better arrangement of the exhibits, which were shown without any apparent reference to their date, or importance in horological development.

The second section of the exhibition was, as previously mentioned, devoted to the products of present-day makers. Practically every modern British maker was showing a full range of products and these ranged from simple time-pieces to elaborate chiming and striking clocks. British watches were also shown, and the remarkable achievements of modern British horologists in this field should give great cause for satisfaction. The firm of Smiths English Clocks, Ltd., had a full range of clocks and watches on show, and the company's subsidiary firms exhibited tower clocks, industrial time-recorders, process timers and electric master clocks connected to circuits of dials. Hairsprings and watch jewels, both products that formerly had to be imported from abroad, were also shown, and even watch hands are now made in this country.

The Synchronome Company, Ltd., exhibited a standard master clock, driving a circuit of dials and a " programme ringer " which can be set to switch circuits or ring bells at any preset time, and to any daily programme. Beside this was a very fine example of a Shortt-Synchronome free pendulum clock, a timepiece which is undoubtedly the finest pendulum clock in existence, and is standard in many observatories all over the world.

Synchronous electric clocks in several new designs were shown by Ferranti, Ltd., and fine marine and survey chronometers were exhibited by Thomas Mercer, Ltd. One interesting exhibit made by this firm was a marine chronometer mechanism, mounted in rectangular plates and enclosed in a Perspex cylinder which enabled it to be studied from every angle and its action inspected.

Other novelties included a camera clock, which enables the hours, minutes and seconds to be photographed on a corner of every frame of a cinematograph film. This was designed to help in research work, and has proved most useful where the exact instant of exposure of each frame of a film must be known. The clock was developed by the firm of Charles Frodsham and Co., Ltd., which also showed three fine watches, made in the style of the old English lever, just to show that present-day craftsmen's hands had not lost their cunning.

A fine modern automatically-wound tower clock, shown driving a large rectangular dial and chiming and striking on five bells, was shown by John Smith and Sons, of Derby, and another tower clockmaker, Thwaites and Reed, of Clerkenwell, London, exhibited several weight-driven, hand-wound tower timepieces, and a newly developed winding attachment for existing tower clocks that obviates complicated reconstruction of old mechanism.

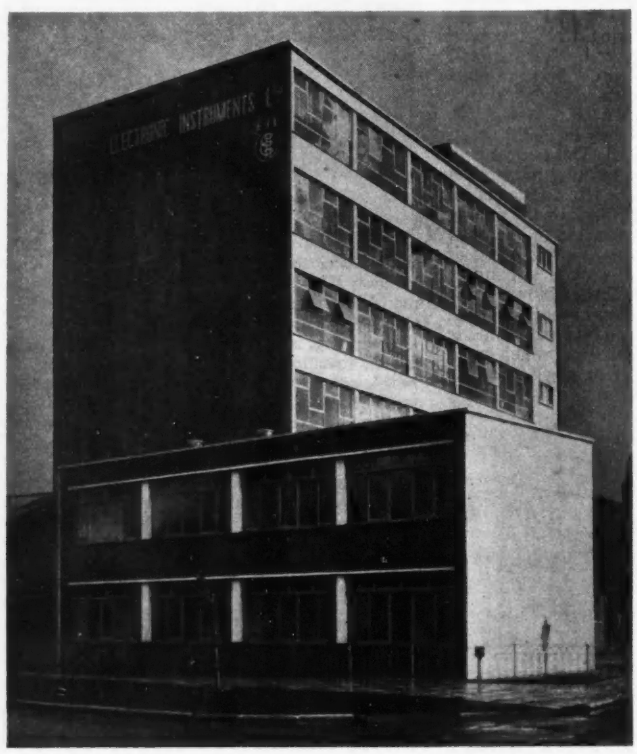
Some fine timepiece and striking movements of unusually high quality and a number of types of chart drum and other industrial clocks, together with a tower clock with gravity escapement and automatic windings, were shown by G. and F. Cope and Co., Ltd., of Nottingham. A novel clock, also shown by this firm, was the " viewer timer," a timepiece designed to indicate on a strip of sensitised paper the duration of viewing of any particular programme by television viewers.

The clock operates by the energising of a combination of four contact fingers which rest on a strip of paper propelled by the clock, and a subsequent examination of the paper shows exactly when the set to which the clock is connected was switched on, or when it was changed from one programme to another and the duration of reception of that programme. The object of this is to assist in viewer research.

The exhibition, which was open freely to the public, was well attended, and at times it was difficult to get near to some of the more popular exhibits. It demonstrated conclusively that, though British horology was pre-eminent in the past and has had some hard times since, its present development is remarkable and its products highly competitive with any in the world.

Electronic Instruments Factory

LAST week we had the opportunity of visiting the recently completed factory of Electronic Instruments, Ltd., at Richmond, Surrey, following its official opening by the Rt. Hon. The Earl of Halsbury on October 4th. Designed by Kenneth Anns, F.R.I.B.A., the building, as illustrated below, is on six floors with large windows on both sides, and laid out to suit the firm's production, which consists of short series of electronic measuring gear of various kinds. The sixth and fifth floors are almost entirely staffed by operatives engaged in assembling and testing, while on the floor below is the meter department, where the precision meter movements are made which are incorporated in many of the firm's designs. Other departments are devoted to development work and research, in particular the chemistry laboratory, where work is carried out in connection with pH measurement. The building also houses a machine shop, glass-blowing shop and drawing office, as well as the administrative offices and a club room.



Electronic instruments factory in Richmond

Formed in 1945, the firm now employs some 150 people, the majority of whom are women. On joining the company each employee is trained by steps to carry out a large number of the operations required, as great flexibility of production is considered essential.

It has been the policy of Electronic Instruments, Ltd., from the beginning, to produce only such equipment as was not being made elsewhere. The result has been a range of precision apparatus which in many cases represented a major advance in instrumentation. The most important group of instruments are those dealing with pH measurement, in which field the company introduced their first direct-reading model in 1947. For the testing of insulating material a 20,000,000 megohm-meter has been produced and, at the other end of the scale, a milliohm-meter was designed to read to fractions of a milliohm with accuracy. Millisecond time measuring gear and valve voltmeters such as the " Micovac " standardised by the Admiralty, are other specialities on which the company is engaged.

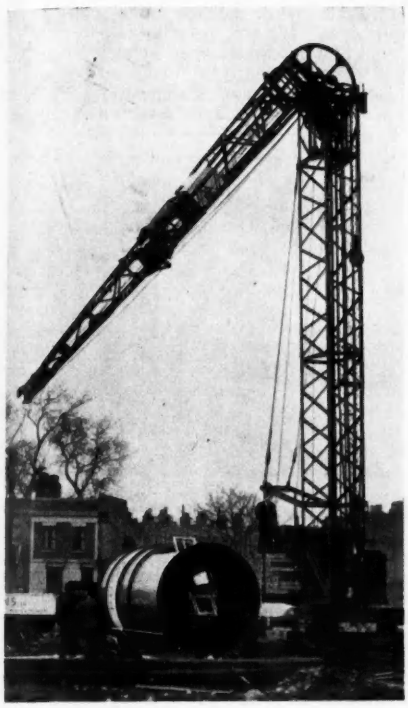
One of the most remarkable developments is the " Vibron," a small condenser, the capacity of which is varied by imposing a periodic vibration upon one plate, the other remaining fixed. This enables an electric charge to be amplified as alternating current to an extent unattainable with valve voltmeters. It is stated that with the " Vibron " resistances of the order of 1000 million megohms and currents of a billionth of

One of the assembly floors at the top of the building, lit by large windows on both sides

an ampere can be measured. The device, it is thought, will find important applications in nuclear physics. At present all the available output is being used to equip machines for controlling the weight of tobacco in cigarettes.

Self-Erecting Electric Tower Cranes

AN electric tower crane, incorporating means of self-erection, is now being marketed by the contractors' plant department of George Cohen Sons and Co., Ltd., in two models, the "Everest" T.16 and "Everest" T.30. The capacity of the "T.16" ranges from 35 cwt at a radius of 21ft



Jib of tower crane being lowered against mast for dismantling

and a height of 102ft to 19 cwt at 52ft radius and a height of 69ft. The larger "T.30" machine is designed for loads of 59 cwt at 31ft radius with a lift height of 134ft and 23 cwt at 72ft radius and a height of 85ft. Both cranes combine means of simple, quick erection with mobility, and the operating ropes remain in their guides at all times, the process of dismantling and re-erection being carried out using the crane's own motors.

To dismantle one of the cranes the jib is first lowered, until it lies vertically against the mast, as shown in the accompanying illustration. Securing bolts are then removed from hinged points in both mast and jib, the derricking ropes are re-anchored to a special plate on the upper portion of the mast and this upper portion, together with the upper part of the jib, is then lowered by the hoist motor until both are in position "head down" against the lower sections. Finally the folded mast and jib are partially disconnected so that they are in effect hinged at the forward edge of the slewing superstructure and are then lowered and the free end positioned on a special saddle fitted to a flat platform lorry. When the ballast has been removed from the superstructure the chassis of the crane is jacked up and fitted with pneumatic-tyred road wheels. For erection this procedure is reversed.

All crane motions are electrically driven and travelling, slewing, derricking and hoisting can be carried out either simultaneously or separately, as required. Each motion is fitted with a powerful brake and its gearing totally enclosed in an oil bath. Two control platforms are provided, one at the top of the mast and one at the bottom. Electric control is fitted throughout, no mechanical control linkage being used on any of the motions.

The cranes operate on a rail track and they can negotiate curves of 11ft 6in to the inner rail, the "T.16" having a track gauge of 9ft 2in and the "T.30" one of 9ft 10in. Each crane has a travelling speed of 98ft per minute. The smaller capacity machine has a hoisting speed of 130ft per minute for loads up to 23 cwt and 66ft per minute for loads up to 35 cwt. The heavier capacity crane hoists loads up to 26 cwt at 130ft per minute and loads up to 59 cwt at 66ft per minute.

Improved Control Cabinet for Emergency Lighting Equipment

AN improved design of control cubicle for use with emergency lighting equipment has been introduced by Nife Batteries, Redditch, Worcester. It is being supplied with the Nife-"Neverfayle" emergency lighting sets for pilot systems where the lamps are only illuminated on mains failure, and for changeover systems where the lamps are normally fed from the a.c. supply and are automatically transferred to the battery on mains failure.

The battery, which consists of nickel-cadmium alkaline cells, is mounted separately on a single-tier stand and does not require a special battery-room. The steel cabinet is smoothly contoured and finished in battleship grey. The instruments, warning lights and fuses are readily accessible on a sloping panel, as can be seen from our illustration.

The contactor installed in the cabinet is spring-controlled and the operating coil works in conjunction with an economy resistance fed by direct current from a full-wave, bridge-connected selenium rectifier. Positive operation of the contactor, within close voltage limits, is achieved by an automatic control device incorporating an auxiliary relay for switching in and out the economy resistance. The relay is set so that it will not close until the mains voltage is higher than that required for a positive closure of the contactor, thus protecting the contactor coil and its associated auxiliary rectifier against burn-out.

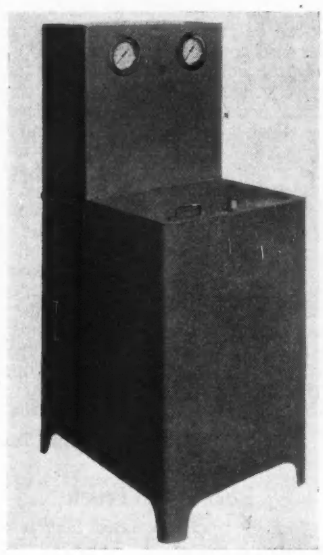
The cabinet also contains a vacuum-impregnated double-wound transformer with tapped primary and full-wave bridge-connected selenium rectifier for recharging a discharged battery in fourteen hours. In the "maintained range" of equipments an additional transformer is installed to feed the emergency lights at reduced voltage from the a.c. supply while it is available. With the exception of the larger sizes, control is effected by one master rotary switch having four positions: "off," "stand-by," "charge and stand-by," and "charge" only. The charge rate is regulated by means of two four-position tapping switches for coarse and fine control.

The equipments are available for both "standard" and "tropical" rating.

Improved control cabinet for emergency lighting equipment

Component Cleaning Machines

PARTICULARS have been received of machines now being made by the Electro-Chemical Engineering Company, Ltd., Queens Road, Weybridge, Surrey, for the batch cleaning of small components by "di-phase" cleaners. This di-phase process, originally introduced in the United States, employs two different and immiscible liquid cleaners which are applied to the workpiece almost simultaneously either by dipping or spraying. One liquid removes



Di-phase cleaning machine in which the work is moved through immiscible cleaning solutions for removing oil and water soluble dirts

oil-soluble dirt and the other water-soluble dirt. The cleaning solutions are non-toxic and rust inhibiting, and are used in concentrations of only 3 to 5 per cent. They are suitable for use with workpieces made of ferrous and non-ferrous metals, including zinc, aluminium and magnesium.

One of the new "Efco-Agidip" machines for use with this cleaning process is illustrated above. The tank containing the cleaning solutions is fitted with a reciprocating work container. This container is raised and lowered in the tank during the cleaning cycle by a double-acting pneumatic cylinder. Two 3kW thermostatically controlled immersion heaters fitted in the base of the tank maintain the solutions at the required temperature. When the machine is in operation a regular and rapid up-and-down movement of the work container through the two layers of di-phase solutions for a period of about two minutes is stated to be sufficient to remove both oil and water-soluble dirts, oils, &c., from the metal surfaces. After cleaning the work can be dried by an air blast or in a hot air machine supplied for the purpose by the makers.

The cleaning machines are made in two sizes with capacities of 20 lb and 65 lb, the smaller machine having a tank 2ft by 1ft 5in by 3ft deep, and the larger machine a tank 2ft 10in by 1ft 7in by 3ft deep. If required a filter can be fitted in conjunction with a circulator for removing dirt suspended in the cleaning solutions whilst the machine is in operation.

Motor-Driven Chain Transmission Unit for Carding Engines

WE illustrate a cotton carding engine equipped with a new form of individual drive consisting of a motor and chain drive unit which is mounted on the carding engine itself. In this position the motor drive does not encroach on floor space. It was developed by The General Electric Company, Ltd., in conjunction with Renold Chains, Ltd., and is intended primarily for converting existing carding engines to individual electric drive.

The driving motor is a totally enclosed, dust-proof, squirrel-cage machine. Control of the motor is effected by a direct-to-line contactor starter, which incorporates saturable-core magnetic overcurrent releases to avoid unnecessary tripping when starting the carding engine, without prejudice to the normal overcurrent protection of the motor.

The chain drive consists of a 0·375in pitch duplex chain with a length of 132 or 134 pitches according to the combination of wheels employed, and suitable for working at a centre distance of approximately 11in. Alternative motor pinions of twenty and twenty-one teeth are available, together with a range of driven wheels having from 111 to 116 teeth. With a motor speed of 960 r.p.m., a combination of the pinions and wheels can be provided to give a fine range of cylinder shaft speeds between 168 and 181 r.p.m., to cover the normal requirements of the user. The drive is enclosed in a cast aluminium oil-tight chain case, which has been designed to be equally suitable for right or left-hand motor mounting. The driven chain wheel is normally supplied for driving through a dog clutch, but alternative arrangements for mounting on the cylinder shaft can be made. A pulley is mounted on the motor shaft external to the chain case to provide a rope drive to the stripping brush, the drive to the main card cylinder being disconnected by the clutch during the stripping operation. This pulley is also used if grinding by the "slow grinding" method is preferred, the doffer being driven through a crossed rope with the main drive declutched. If grinding at normal operating speed is adopted, a reversing contactor starter is provided so that the card can be driven in the reverse direction with the clutch engaged.

Fork Lift Truck

THE fork lift truck illustrated here is a new production of Ransomes, Sims and Jefferies, Ltd., Ipswich, and although it is rated at 2000 lb

Fork lift truck with a capacity of 2000lb at 20in centres

at 20in centres, it is actually capable of handling loads up to 2000 lb at 24in centres. The machine is made in four models with lift heights of 8ft, 10ft, 12ft and 14ft, the overall heights with the mast lowered being 71in, 83in, 95in and 107in, respectively. A new method of mast mounting enables the masts to be removed or replaced in a few minutes. With its astride turning radius of 71in, the machine is able to negotiate intersecting aisles 63in wide, and it can be used for stacking at right angles in aisles 135in wide when handling pallets 48in long.

The truck is fitted with an eighteen-cell, 360A-hours capacity battery and the drive is through a worm reduction gear and a differential giving four speeds in either direction up to 6 m.p.h. when unladen and 5·5 m.p.h. laden. A vane pump driven by a separate motor provides the hydraulic power for lifting and tilting. Separate self-centralising hydraulic control levers are conveniently situated at the driver's right hand.

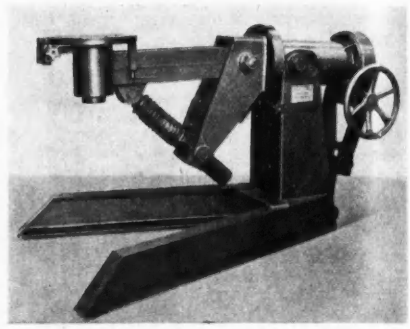
Hydraulic brakes are fitted to the drive axle, which can be equipped with solid, cushion or pneumatic tyres to the wheels. The steering axle is mounted on semi-elliptical laminated springs and can also be equipped with cushion or solid-tyred wheels.

Special attention has been given to facilitating service attention. On removing the battery the entire control housing can be hinged back without disturbing any hydraulic or electrical connections. This provides easy access to motors, resistances, hydraulic pump, &c.

Welding Positioner

WE illustrate below a new manually operated "Twinner-Aronson" balance positioner for welding shops, now being made by Donald Ross and Partners, Ltd., 1–3, Arlington Road, London, N.W.1. This machine is designed to handle workpieces weighing up to 40 cwt, and a smaller model of 12½ cwt capacity is also made.

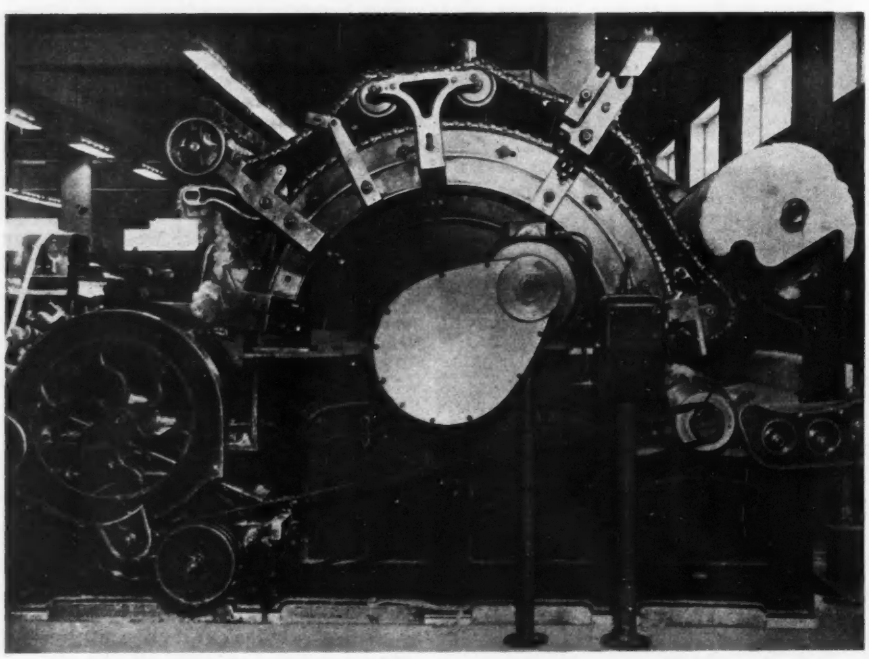
The work arm is mounted in a trunnion-supported barrel on the column of the machine, and at the rear the barrel is connected through a yoke and heavy screw to the main base. Through this screw the work arm can be raised, with a full load on the table, up to 30 deg. to the horizontal. The arm assembly can be tilted by means of a handwheel when a clutch is engaged, and when this clutch is disengaged the arm is quite free for manual manipulation. A band brake on the barrel end of the arm can be applied



2-ton capacity positioner for welding work

to hold the arm in any required position. The angle of the table can be adjusted to balance the work by means of a screwed shaft extending at an angle from the outer end of the arm to a bracket at the barrel end, where the arm is pivoted.

In the illustration a 17in diameter work plate is fitted on the work arm, but, if required, a larger plate or a cruciform work holder can be supplied together with the necessary clamps. The work plate rotates freely on the arm and it is fitted with a friction brake as well as a locating peg which operates in conjunction with indexing holes in the plate.



Cotton carding engine individually driven by an electric motor with chain transmission. The motor chain drive unit (centre) is mounted on the carding engine, leaving the floor clear

Molten-Metal Pyrometer

A MOLTEN-METAL pyrometer consisting of a thermocouple with compensating leads and an indicator or recorder, suitable for measuring the temperature of non-ferrous metals and cast iron, has been developed by the Cambridge Instrument Company, Ltd., 13, Grosvenor Place, London, S.W.1.

For temperatures up to 1100 deg. Cent. the thermocouple elements are base metal (chromel-alumel, batch 684), about 36in. long. These elements are protected by a removable sheath (with a closed end) made of graphite, which, being inherently self-lubricating, does not bind when heated and is, therefore, easily replaceable. This sheath is fitted at one end of a steel tube about 30in long, which carries the thermocouple leads to a junction box. A shield on the steel tube protects the junction box against radiant heat from the molten metal and thus insulates the cold junction of the thermocouple from severe temperature changes. Replacements can be made by disconnecting the leads at the junction box terminals and withdrawing the thermocouple.

For temperatures between 1100 deg. and 1550 deg. Cent., and for molten cast iron, the thermocouple elements are of rare metals (for example, platinum, platinum-rhodium). In general, the thermocouple is similar to that used for temperatures up to 1100 deg. Cent., except that the tube is made of nickel-chrome instead of mild steel, and that the element wires are about 48in

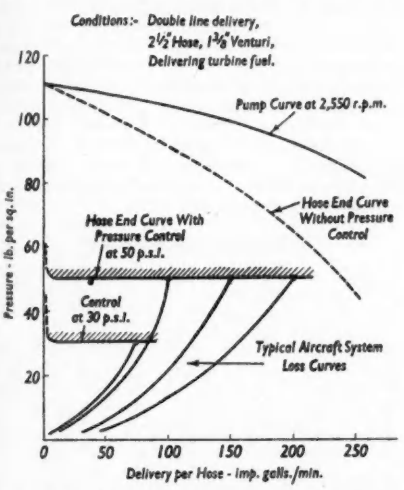
long, the excess length being wound on small reels in the junction box. As the tip of the thermocouple deteriorates in use it is cut off and the loss is made good by unreeling some of the surplus wire, the junction being renewed by twisting the ends of the wire together.

In both thermocouples the average time-lag, when the graphite sheath is new, is 25 to 28 seconds, falling to about 18 to 20 seconds as the sheath becomes thinner with use. The compensating leads, which make the measurements independent of the cold junction temperature, are asbestos covered and are carried in steel conduit tube to the indicator or recorder.

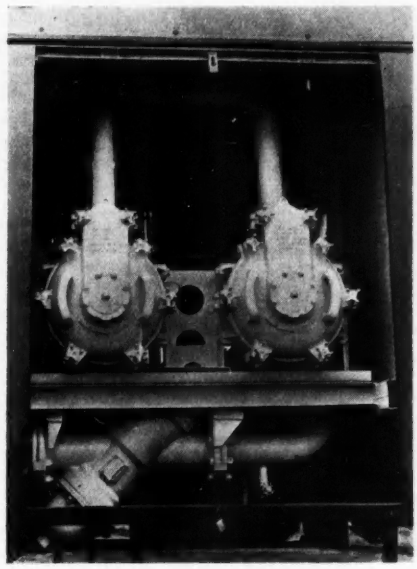
One form of Cambridge indicator which is particularly suitable for dark situations and can be read from a distance has a brightly illuminated scale with a total effective length of 20in (which can be coloured red, green or white to show working limits); this scale moves across a datum mark in a rectangular window. Alternatively, wall type indicators or portable indicators can be supplied. The thermocouple readings can also be recorded on a Cambridge electronic recorder.

Refuelling Vehicle

A TANKER intended to refuel large aircraft rapidly has been designed by the British Petroleum Company for their Aviation Service, who know it as the "Cornwall," and is built by Thompson Brothers of Bilston, Staffs. We depict a version on a Leyland "Hippo" chassis, such as has been used for many other mobile refuellers, including the "Dorset" described, on page 474 of these columns, on October 12, 1951.

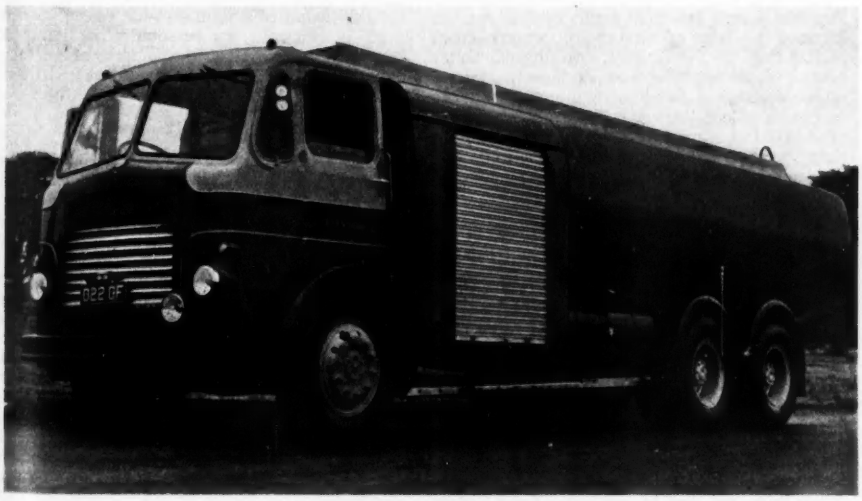


The "Cornwall" fueller performance envelope



Fine particle filters and pressure control valve

To ensure immediate availability, the delivery pump is geared to the oil engine of the chassis with a 2·43 : 1 step-up from the gearbox power take-off. The pump performance is given in the accompanying graph. The 2½in hoses are used for underwing (pressure) refuelling at high outputs, but the vehicle also has a pair of 100ft long 2in hoses which can handle 100–130 g.p.m. and are long enough to fill both wing-tip tanks of an air liner at once. Our illustration shows the "Rellumit" fine particle filters, accessibly located, and the pressure control valve which throttles the fuel flow to give the required into-aircraft pressure. The circuit used is designed for low pressure losses, 30 lb per square inch drop from pump to hose end being achieved; the provision for transferring fuel from the trailer can be used for bottom loading of the tanker. An optional facility is that of defuelling; in this case a meter is provided to record the amount of fuel removed from the aircraft. When suction connections have to be made, as for defuelling or bottom loading, Avery-Hardoll self-sealing couplings are employed. All pipework and the pump itself are hot-tinned for cleanliness, and the tanks are treated internally with "Prodorfilm"; gasoline or kerosene fuels can be handled. Examples of this appliance are already in use in Switzerland, Denmark and France.



The "Cornwall" aircraft refueller has a capacity of 3400 Imperial gallons and can tow a 2500-gallon trailer

Symposium on the Use and Welding of Aluminium in Shipbuilding

A JOINT committee representing the Institute of Welding, the British Welding Research Association, the Institution of Naval Architects, the British Shipbuilding Research Association, and the Aluminium Development Association has organised a symposium on "The Use and Welding of Aluminium in Shipbuilding," to be held on December 7th and 8th, in the Weir Lecture Hall of the Institution of Naval Architects, 10, Upper Belgrave Street, London, S.W.1.

The papers will be read as follows :—

Wednesday, December 7th, 10 a.m.—12.30 p.m.: First Session—Welding Processes and Techniques (Chairman, Sir Charles Lillicrap, K.C.B., M.B.E., D.Sc. (Eng.)).

"The Selection and Use of Processes for Welding Aluminium in the Shipyard," by P. T. Houldcroft, B.Sc. (Eng.Met.); "Recent Developments in the Metal-Arc Welding of Aluminium Alloys in Great Britain," by W. I. Pumphrey, M.Sc., Ph.D.; "Process Variables and the Control of Quality in Welding NP5/6 Plate," by P. T. Houldcroft, B.Sc. (Eng.Met.), and A. A. Smith, B.Sc.; "The Inspection and Control of Weld Quality in Aluminium Structures," by A. E. W. Rogers; "Inspection and the Control of Weld Quality in the Inert Gas Welding of Aluminium Alloys," by J. G. Young, B.Sc., and J. E. Tomlinson, B.Sc.

2.30—5 p.m.: Second Session—Materials and Design (Chairman, Mr. R. B. Shepheard, C.B.E., B.Sc.).

"Aluminium Alloys for Shipbuilding Purposes," by H. J. Adams, M.Sc.; "Welded Aluminium Alloy Structures: the Strength and Performance of Welded Joints and Their Influence on Design," by C. P. Oldridge, R.C.N.C.; "The Selection of Filler Materials for Welding Aluminium Alloys," by P. T. Houldcroft, B.Sc. (Eng.Met.), and F. Fidgeon, B.Sc.; "The Mechanical Strength of Welded Joints in Aluminium Alloy Plating," by N. V. Almy, A.M.I.N.A.; "The Testing of Welded Aluminium Structures," by A. M. Mackie, B.Sc., D.I.C., A.F.R.Ae.S.

6.30 p.m.: Reception by the Chairman and Council of the Aluminium Development Association at 33, Grosvenor Street, London, W.1. Technical films will be shown during the reception.

Thursday, December 8th, 10 a.m.—12.30 p.m.: Third Session—Applications (Chairman, Mr. R. C. Thompson, C.B.E., M.A.).

"Scandinavian Experience with Metal-Arc Welding of Aluminium in Shipbuilding," by Arne Brinck, B.Sc., M.E., M.N.I.F.; "Dimensioning of Light Alloy Structures in Shipbuilding," by Professor Ir. H. E. Jaeger; "The Construction of Light Alloy Superstructures on the Packet Boats 'Flandre' and 'Antilles,'" by Pierre Vidal, Ingenieur E.N.; "Some Case Histories of Aluminium Alloy Small Craft," by H. Goodwin; "The Welding of Small Marine Craft in Aluminium Alloy," by W. H. Dann, M.B.E., B.Sc., A.M.I.N.A., Whit. Sch.; "Aluminium Alloys in Ships' Auxiliary Equipment and Fittings," by E. C. Goldsworthy.

2.30—5 p.m.: Fourth Session—Applications and Economic Factors (Chairman, Sir Victor Shepheard, K.C.B.).

"Design and Construction of Welded Aluminium Deckhouses," by John F. Leathard, B.Sc., Ph.D., A.M.I.N.A.; "All-welded Aluminium Deckhouses," by A. R. C. Paterson; "The Use and Welding of Aluminium in Shipbuilding," by W. G. Warren, R.C.N.C.; "The Economics of the Use of Aluminium in Ships," by W. Muckle, M.Sc., Ph.D.; "The Influence of Fabricating Methods on the Cost and Quality of Welding," by J. G. Young, B.Sc., and J. E. Tomlinson, B.Sc.; "Aluminium Alloy Material: Economic and Other Advantages Related to Two Classes of Ships," by James Lenaghan.

AIR-COOLED DIESEL UP-RATED.—The small air-cooled diesel engine built by Petters, Ltd., Staines, has now been made available with an output of 3 b.h.p. at 1800 r.p.m. This modification will allow the "PAZ-1" to drive 60-cycle alternators, besides giving improved power-weight ratios in other applications.

Industrial and Labour Notes

Industrial Relations

In a speech, last Friday, at the Conservative Party's annual conference, the Minister of Labour, Sir Walter Monckton, Q.C., referred to recent talks between the Prime Minister and representatives of the British Employers' Confederation, the Trades Union Congress and the nationalised industries on the subject of industrial relations. He said that those discussions, which were now being continued by a committee of the National Joint Advisory Council, had revealed a genuine and real desire to find a way to avoid all unnecessary strikes. Among the matters kept in mind during the discussions was the time taken over negotiations. That, Sir Walter said, was a factor which often made the task of settling a dispute all the more difficult.

Sir Walter went on to plead for a sense of proportion in considering industrial disputes. He said that recent figures from the International Labour Organisation had shown that from 1947 to 1954, on average, ten times as many days were lost per thousand workers in the U.S.A. as in this country. Moreover, in the series of strikes from which this country had suffered during the summer, the T.U.C. had recognised to the full its share of responsibility in so far as inter-union discord was concerned. On the matter of co-partnership and profit sharing, Sir Walter said he did not doubt the psychological importance of giving the workers in appropriate cases either shares in the business or a share in the profits, with the aim of giving employees a specific stake in the enterprise for which they were working. The Chancellor of the Exchequer, he added, had already had steps taken for advice on taxation matters to companies which decided to establish such schemes. Furthermore, Sir Walter said, the Ministry of Labour had a personnel management advisory service which was always willing to discuss schemes with firms and to suggest conditions that ought to be fulfilled before they were introduced.

Employment and Unemployment

The Ministry of Labour has stated in its latest report on the employment situation in Great Britain that at the end of August the total working population was 24,009,000, which was 93,000 more than at the end of July. The total strength of H.M. Forces was 793,000, and the number in civil employment was 23,028,000 (15,232,000 men and 7,796,000 women).

The Ministry says that the August total for civil employment was 90,000 higher than the July figure and 275,000 higher than a year previously. The increase in August was, of course, mainly the result of school-leavers entering employment. The number at work in the basic industries was 4,027,000, a net increase of 6000, the additions being in the gas, electricity and water supply industries and in agriculture. There was no change during August in colliery manpower, the number of wage earners on the books being 702,000, compared with 706,000 at the end of August, 1954. In the manufacturing industries there was an addition of 45,000 to the labour forces during August, the total at the end of the month being 9,273,000. By far the largest increase (19,000) occurred in the engineering, metal goods and precision instruments group, where the number employed was 2,779,000. There was also an addition of 8000 to the labour force of the vehicle building industry, bringing the total to 1,242,000. In industries apart from the basic and manufacturing groups, the principal change in August was in building and contracting, where an addition of 14,000 brought the number employed to 1,482,000.

The Ministry's latest unemployment figures show the position on September 12th, when 202,221 people were registered as out of work, compared with 199,693 on August 15th. The September figure, which represented about 0·9 per cent of the total number of employees, included 19,000 who were temporarily stopped. The number who had been unemployed for more than eight weeks was 67,000. The Ministry's report adds that in the week ended August 27th about 54,000 operatives in manufacturing industries in the country were stated to be on short time, losing fifteen hours each on the average. To offset that, there were 1,560,000 operatives who worked an average of eight hours' overtime.

Efficiency in the Steel Industry

In the latest issue of its *Monthly Statistical Bulletin*, the British Iron and Steel Federation surveys the present state of the steel industry's efficiency. It says that while the industry's output has risen by five-eighths since the war, the number of workers employed has risen by no more than one-eighth. This is one way, the Federation comments, of bringing into focus the improvement in efficiency that has resulted from the industry's modernisation and development programmes. It is pointed out, of course, that in the steel industry, as in all manufacturing industry, the pursuit of efficiency has consisted essentially in the search for means whereby the maximum output might be obtained from the minimum input of resources. The task of management is to use the available factors of production—raw materials, fuel, equipment and labour—as economically as possible, the final criterion of success being the level of costs.

The survey examines the kind of measures which have been taken in the British steel industry to economise each of the principal factors of production and so to reduce the unit cost of steel. These measures include economy in raw materials and fuel, in plant and equipment, and in labour. On this last point, the survey says that in the steel industry, economy in labour has had the full support of the unions, whose leaders are as "productivity-conscious" as any in this country. Perhaps the most obvious means to this end, the survey continues, is the provision of reasonable incentives. In the steel industry the wages of skilled men have for many years included a tonnage element, thus giving an incentive to maximum production. Since the war these arrangements have been extended and now cover the majority of workers in the industry.

At the same time, it is by large-scale capital investment that the main economy of labour—as well as of materials and fuel—has been achieved. The survey emphasises that this has provided the master-key to increased efficiency in all its aspects. The industry's post-war investment programme has not only increased the capacity of all sections ; it has made possible the elimination of obsolete plant and a gradual increase in the average size of furnace. For example, the average annual output of blast furnaces producing basic iron has risen by 56 per cent, from 94,000 tons in 1946 to 147,000 tons last year. In open-hearth steelmaking the increase has been of similar proportions—from 36,800 tons to 58,000 tons. Additional sinter plants, bigger blast furnaces and steel furnaces, more mechanical handling equipment and the adoption of continuous rolling processes have all enabled each man to handle a larger tonnage than before. Labour productivity and fuel efficiency have thus been improved to a marked degree.

Overseas Trade Fairs

In the current issue of the *Board of Trade Journal*, there appears an article dealing with the United Kingdom Government's practice concerning overseas trade fairs. It says that British participation in these fairs has been subjected to a constant stream of criticism. On the one hand, British industry and the British Government are repeatedly reproached for failure to install a display as imposing as that provided by somebody else. In addition, British manufacturers are inclined to complain, and with some reason, about the increasing number of trade fairs and the burden thus placed upon them not only as regards money, but even more as regards staff time. British manufacturers, the article comments, suspect that some of the fairs which are being organised owe much less to commercial demand than to the desire of individual promoters for profit and of governments for prestige.

The Board of Trade takes the view that "official policy starts from the belief that the object of taking part in trade fairs is to sell goods and that selling is the job of individual firms." The individual firm will therefore decide, the article states, as a matter of commercial judgment, whether participation in any particular trade fair is likely to result directly or indirectly in extra sales (or the avoidance of a decline in sales) sufficient to justify its cost. It would be entirely wrong, the Board of Trade asserts, for a government department to attempt to influence this commercial decision. The absence of "official encouragement" does not mean, therefore, that the Board of Trade has written off trade fairs as ineffective ways of selling goods, for such is certainly not the case. As a broad generalisation, however, the article continues, it does seem to be true that British firms attach less importance to trade fairs as a means of selling than do their rivals in a number of other countries, and tend to leave a greater share of responsibility in this matter to their agents. The Board of Trade agrees that there are many ways of promoting sales, and it may well be that others are better or more suited to the circumstances and qualities of particular firms than is exhibiting at trade fairs. The Board says that the best advice it has been able to obtain is that exhibits in trade fairs should, as a rule, only be undertaken as an integral part of an organised promotion campaign by many media in a market where channels for distributing the goods have already been established. Though a "flash-in-the-pan" exhibit may sometimes be justified as a method of testing a new market or obtaining agents, its results are likely to be disappointing if it is unsupported in other ways.

Educating Young Workers

Some preliminary details have been issued about a conference on "The Education of the Young Worker," which is to be held at Oriel College, Oxford, from April 7 to 13, 1956. It is being organised by the Department of Education of Oxford University, with the help of a committee, under the patronage of H.R.H. The Duke of Edinburgh. The intention is to bring together representatives of industry, education, trade unions, the youth employment service and voluntary organisations, for discussion. In particular, the conference will consider the needs of young workers preparing for relatively unskilled occupations in various industries and public services, whose brief training offers few opportunities for intellectual and personal development. Among the questions to be discussed is what education do such young workers need for efficiency, for personal growth and for responsibility ? Full particulars about this conference can be obtained from the Department of Education, 15, Norham Gardens, Oxford.

Taxation of Profits and Income

The Federation of British Industries has published, under the title of *The Taxation of Profits and Income*, a digest of the three reports of the Royal Commission on the Taxation of Profits and Income and of the two reports of the Millard Tucker committee. It is explained that "the sheer volume and complexity of the matters discussed in the reports deter the ordinary person from studying them and tempt him to leave the subject to administrators and experts." Nevertheless, many more people are closely concerned in the proposals to reform the structure of the taxes than can "afford the time to read through the reports." The digest has therefore been prepared by Mr. Frank Bower, chairman of the F.B.I. taxation committee, in the hope that it will prove to be a useful record for quick reference.

The digest may be obtained (price 5s.) from the Federation of British Industries, 21, Tothill Street, London, S.W.1.

Continental Engineering News

British Exhibition in Copenhagen

Great importance is being attached to the British Exhibition at present being held in Copenhagen under the joint patronage of Their Majesties Queen Elizabeth II and King Frederick IX, both as regards development of trade between Britain and Denmark, and the strengthening of our friendship with the Scandinavian countries. The exhibition was opened on September 29th by King Frederick in the presence of the Queen of Denmark and members of the Royal Family and the Government, the British Government being represented by the Right Hon. Peter Thorneycroft, President of the Board of Trade.

In the exhibition, which has been organised by the British Import Union of Denmark in co-operation with the Federation of British Industries, some 600 British manufacturers are represented on stands covering a total area of over 10,000 square metres. The two centres are the reconstructed Forum exhibition hall, which for the occasion had to be extended by 40 per cent by means of prefabricated temporary buildings, and the Tivoli Gardens, near the main railway station.

A very wide variety of industrial and consumer goods is being shown, particularly in the field of textiles and of manufacturers in the chemical, plastics, and metal industries. The products of the last-mentioned sectors are of special and increasing interest to Denmark as the growth of home industries proceeds. Most of the engineering and technical exhibits are housed in the Forum, where in the temporary halls the British motor-car industry is showing practically all the makes current in Denmark. Also on view here are products of the aircraft industry, motor accessories, agricultural tractors and road construction machinery, as well as an exhibition of structural glass, including a 26ft model of a plate glass line.

On the ground floor of the main hall are to be seen the products of the iron and steel and the non-ferrous industries, as well as of the engineering and chemical industries. Machine tools are represented by items such as automatic lathes, drills, grinding and milling machines, and equipment for the injection moulding of plastics. Other fields include compressed air and electric hand tools and a very full range of precision measuring, gauging and inspection equipment. Of particular interest to the public appear to be the products of the chemical and plastics industries, which have undergone such great development during and since the war, while the stand of the Atomic Energy Authority, showing the application of isotopes in industry, medicine and research, is also proving a great attraction. The electronics industry is being represented by a number of component manufacturers, as well as by firms showing radio and television equipment. On the balcony of the Forum are to be found photographic and kinematographic apparatus, as well as scientific instruments, business machines and office equipment. An exhibition of books and periodicals arranged by the British Council is well frequented.

Among the largest of the stands at the Tivoli are those of three large oil companies. The main interest here, however, centres upon the consumer goods, which are very fully represented; the most important section is that of the textile industry, including the synthetic fibres industry, which occupies three adjoining temporary halls and the completed portion of the new Tivoli Concert Hall. Also on show here are agricultural machinery, contractors' plant and items illustrating the application of light alloys to industrial and naval construction. A more popular note is struck by the presence of a London bus and a replica of an English "pub," while much interest is being shown in the aircraft models at the stand of British European Airways and the panoramas exhibited by the Port of London Authority

From October 12th to 15th H.R.H. the Duke of Edinburgh is visiting Copenhagen in the Royal yacht "Britannia." Many sporting and cultural events have been arranged to mark the occasion, including a nightly military tattoo by British and Commonwealth units at Roseborg Castle. The exhibition is closing on October 16th.

The present exhibition is the third of its kind, the other two having taken place in 1932 and in 1948. It also marks the twenty-fifth anniversary of the formation of the British Import Union by a group of Danish business men. From 1930 until the outbreak of the second world war Britain's share of Denmark's total exports remained remarkably constant, varying from 68 per cent in 1932–33 to about 54 per cent in 1938–39, while Danish imports from Britain increased from 14·5 per cent in 1930 to a maximum of 37 per cent in 1937, then falling off slightly. The immediate post-war period saw a reversal of the position (imports 40 per cent, as against exports 30 per cent in the second half of 1946). However, the previous pattern quickly returned, with Danish exports and imports remaining since 1949 on a level around 44–36 per cent and 34–28 per cent respectively. In terms of currency Danish exports to the United Kingdom in 1930 amounted to Dkr. 948 million, while the figures for 1939 were 826 million, and those for 1946 and 1954 513 million and 2399 million respectively. Imports from Britain in 1930 were to the value of Dkr. 250 million, the figures for the other years mentioned being 572, 1288 and 2156 million kroner respectively. Most of the British exports to Denmark consist of raw materials and manufactures, while Denmark supplies mainly agricultural produce. It is a point of complaint with the Danes that the terms of trade have moved strongly against them since the war. For example, it is stated that the price of butter has increased by 157 per cent since 1939, while the price of coal has risen by 425 per cent and the price of British strip iron and pig iron by 222 per cent. The hope is expressed in Danish circles that with the dismantling of central control of the trade in agricultural products, which has now begun, efficient merchants may be able to bring about a more equitable state of affairs.

German Inland Shipyards

The order books of German inland shipyards amounted on August 1st to some 180,000 tons, according to Press reports. Of this total, some 45,000 tons were orders from abroad, including some 1500-ton tankers. The majority of the ships are diesel-engined freighters of 1000 tons, in addition to which there are tugs and coastal vessels.

German Car Industry

As reported, the Studebaker-Packard Corporation has confirmed the sale of a former Studebaker jet engine plant at New Brunswick, New Jersey, to the Volkswagen Works. The plant is not equipped for car production. It is situated on a 165-acre site and has a floor area of about 400,000 square feet.

Adam Opel A.G., a subsidiary of General Motors, is to step up production to a figure of 1000 cars a day by August, 1956. The new model of the 2500 c.c. "Kapitän," which has an improved body as well as suspension, will begin coming off the line early in September. Its cost of about £780 is £30 higher than that of the old model.

African Engineering News

BY OUR SOUTH AFRICAN CORRESPONDENT

New Vaal River Power Station

The development of the Vaal Basin was taken a stage further when work was begun recently on a new power station a mile from Taaibos to cost about £22,000,000. The first units will be running by the end of 1958, and the whole station will be completed four years later. The establishment of Highveld power station, as it is to be called, in this area, accords with the policy of siting such undertakings on coalfields and where water can easily be had. Highveld will draw the coal it requires from the Coalbrook South colliery and its water from the Vaal River. It will consume about 1,500,000 tons of coal a year when it is in full production. Besides boosting the Rand's supply of electrical power, it will also help to feed the Free State with electricity. It will have an output of 480,000kW. Highveld will be the fourth large power station in operation in the Free State, and will be about the same size as its nearest neighbour. The other three are Taaibos itself, Vaal and Vierfontein. When they are all in full production they will require 7,000,000 tons of coal annually. Together these stations will represent the expenditure of £74,000,000 by the Rand Undertaking in the Free State alone, and Highveld will be the tenth erected by the Undertaking. The stations will be interconnected and their power output pooled, so that there should be no danger of a complete breakdown of supplies. Other development in the Vaal Basin includes £200,000 worth of extensions planned by Raleigh Industries of S.A., Ltd., at Vereeniging, but with the increase of power supplies and an adequate supply of water the whole area should now attract industry on a more considerable scale than heretofore.

New Vaal River Bridge Opened

The new double-track railway bridge across the Vaal River was opened to traffic on July 5, 1955. It replaces a single-track bridge a mile upstream built more than fifty years ago, and as part of the railway improvement programme in the Vereeniging area, which includes the doubling of the main line between Vereeniging and the Orange Free State, the building of a new station and marshalling yard, the doubling of the line between Union and Vereeniging, and between Vereeniging and Midway. The new bridge is the link between the Transvaal and the Orange Free State, and was built at a total cost of £250,000. The height from normal river level to the underside of the steelwork is about 26ft and the spans were designed so that they could be erected on one bank of the river, rigidly connected together end to end, then "end launched" in one piece right across to the other bank without the need for "falsework," which is both expensive and complicated. The decision to adopt this "launching" method was one of the factors which made the construction of a separate bridge for each track imperative, since the mass of steelwork in each bridge, although very large, would be much more manageable for end launching than in the case of one double-track bridge.

In launching a bridge, the spans are supported on rollers which are carried in frames fixed, at intervals, on the river bank, and also on the piers and abutments over which the bridging has to pass. Pulling or pushing or a combination of both is then the usual way of moving the structure forward. For launching this bridge, the rollers carried in the frames fixed on the Transvaal abutment were connected through trains of toothed gear wheels to manually operated cranks. When the cranks were turned the motion was transmitted through the gears to the rollers which were thereby made to rotate. The leading end of the bridge resting on the rollers was of sufficient weight to prevent skidding and since the rollers were held in a fixed position on the abutment, the structure itself was forced to move forward. Thus, the three spans connected end-to-end were launched across the river, being picked up in turn by pier rollers and finally by those on the Orange Free State abutment. The use of the geared rollers provided the desired control throughout the complete operation. Speed of launching could be varied and the large structure brought to rest in any required position to within a very small fraction of an inch. All components of the spans were not fitted when the structure was launched, but the weight of the steelwork moved was over 500 tons, whilst the overall length was approximately 500ft.

Another interesting fact about the bridge is that it rests on coal. The piers of the steel spans are of concrete, brought up some 46ft from the river bed, where the foundations are taken down about 5ft into a deep seam of coal. Whilst the relatively small pieces of household coal are easily broken, large uniform masses such as those found in the bed of the Vaal have a surprisingly large load-carrying capacity.

The Kariba Contract Begun

To implement the proposals already made for preliminary work to start at Kariba this year before the rainy season begins, the Federal Hydro-Electric Board has entered into a contract with the Cementation Company, Ltd., without first calling for tenders. The work involved, which was due to begin in August, will enable the Zambesi to be diverted and will include the construction of a tunnel through the rock on the south bank, and the building of two cofferdams.

500 H.P. Solar "Jupiter" Gas Turbine

BY OUR AMERICAN EDITOR

The Solar Aircraft Company, of San Diego, California, has received a contract from the U.S. Navy Bureau of Ships calling for the design, development and construction for delivery by December, 1956, of a "packaged" 300kW, 60 c/s, a.c. generating set using the constant-speed version of the 500 h.p. Solar "Jupiter" gas turbine as a prime mover. The present contract is a sequel to earlier ones awarded to the company by the U.S. Navy, sponsoring the development of the "Jupiter" series of gas turbines which is reviewed in this article.

THE initial "Jupiter" series gas turbine was delivered by the Solar Aircraft Company to the U.S. Navy in 1950, after a development programme of relatively short duration. This prototype engine was designated the model "T–400J" and was applied as a prime mover in a shipboard emergency generator set. The generator set was installed in the destroyer U.S.S. "Timmerman" in January, 1951, becoming the first gas turbine ever to be installed in a U.S. Navy ship. This unit was replaced late in 1954 by one of the later models of the "Jupiter" series.

While the emergency generator set incorporating the "T–400J" engine had a reasonable record for availability during its shipboard use, the job of keeping the set suitable for emergency operation required considerable effort on the part of the U.S. Navy and of the company's staff. The application served to demonstrate the inherent advantages of the gas turbine in marine applications. However, it also became apparent to those concerned with the future of the "Jupiter" series gas turbines that an extensive development programme, aimed at improving the durability and performance of the engine, would be necessary if the engines were to be used in applications where extended operating periods are involved and a long overhaul life is required. Accordingly, a new programme was undertaken under the sponsorship of the U.S. Navy Bureau of Ships, having the following objectives :— (*a*) Redesign of the engine components found to be troublesome in the "T–400J" engine ; (*b*) increase of the power output and the thermal efficiency over those of the prototype unit ; (*c*) conduct of a development programme involving extended engine running times to prove the reliability of the modified engine.

At this stage, the desirability of a multiple-purpose gas turbine engine became evident, and it was decided that the design modifications should allow making either a single-shaft or a two-shaft engine from substantially the same components. The two-shaft or split-wheel configuration, with its inherent torque-multiplication ability, is required for boat or vehicle propulsion, while the single-shaft version, with its high rotating inertia, is ideally suited for electric generator drives, where sudden load changes can occur. The single-shaft engine was designated as the "T–520J" and the two-shaft version as the "T–522J." At a later date, the multiple-purpose concept of the "Jupiter" series engines was extended to include a version of the single-shaft engine, wherein its useful output is provided in the form of compressed air, in addition to shaft power. The compressed air is bled from the discharge of the ten-stage axial-flow engine compressor.

Redesign of Prototype Engine

From a survey of the field of applications it appeared that the original prototype unit rating of 400 h.p. maximum was slightly low and that a unit with a maximum rating of 500 h.p. and a continuous rating of 420 h.p. would be more desirable for long-life applications. The basis for engine ratings in American naval applications involving prime movers of this design has been established as 80 deg. Fah. air inlet temperature, with inlet and exhaust pressure losses of 4in and 6in of water, respectively. It should be noted that the emergency power and continuous power ratings become 590 h.p. and 500 h.p. when based on N.A.C.A. standard day conditions with no inlet or exhaust pressure loss, the basis generally used for rating American aircraft gas turbines.

Accordingly, the redesign was initiated with these horsepower ratings as the goal. The selection of a 1500 deg. Fah. maximum turbine inlet temperature with 80 deg. Fah. ambient conditions established the basic aerodynamic configuration of the unit. From this, it appeared that the airflow requirements would have to be increased approximately 20 per cent over those of the prototype, and that the original two-stage turbine would have to be discarded in favour of a three-stage unit, to obtain the desired efficiency and provide for an adaptation from a single-shaft to a split-wheel arrangement. The only basic mechanical problem encountered with the "T–400J" engine involved the structure of the turbine casing. Under certain transient conditions, primarily at engine shut-down, a large thermal contraction differential would exist between the turbine rotor and stator, resulting in blade rubs. Distortion or warping of the turbine structure also was encountered. In the redesign it was decided to stay with the original arrangement, to incorporate modifications found desirable in the previous development tests, and to redesign the turbine arrangement to incorporate the three-stage wheels and a modified outer case support configuration. The increase in compressor airflow was achieved by the simple expedient of extending the height of the original "T–400J" compressor blading. This had two advantages : (1) a considerable amount of information had been obtained on the basic compressor aerodynamic design, and (2) the existing investment cast master patterns for the blades could be used by simply extending the airfoil contours at the tips.

The turbine redesign, however, was a slightly more difficult problem, the final configuration turning out to have no resemblance whatsoever to the original "Jupiter" turbine. As illustrated in Fig. 1, the first-stage wheel and shaft are an integral component, the wheel being manufactured from Timken 16–25–6 alloy and arc welded to the chromium-molybdenum steel shaft under the turbine roller bearing. The second and third-stage turbine wheels, also made from Timken 16–25–6 alloy, are attached by a retaining bolt to the first-stage wheel. The decision to go to a three-stage turbine left no possibility of using the existing turbine blading ; therefore, it was decided to attempt to achieve a turbine design in which the three rotating stages of the turbine would use the same blade airfoil configuration. This ideal was achieved ; however, it required broaching of the first two stages of the turbine at a slightly different angle to that of the third wheel. In the case of the nozzles, however, it was not possible to achieve this interchangeability. The first-stage turbine nozzle required one blade casting die, and the second and third-stage nozzles were fabricated from a second casting. This attempt at standardisation in the

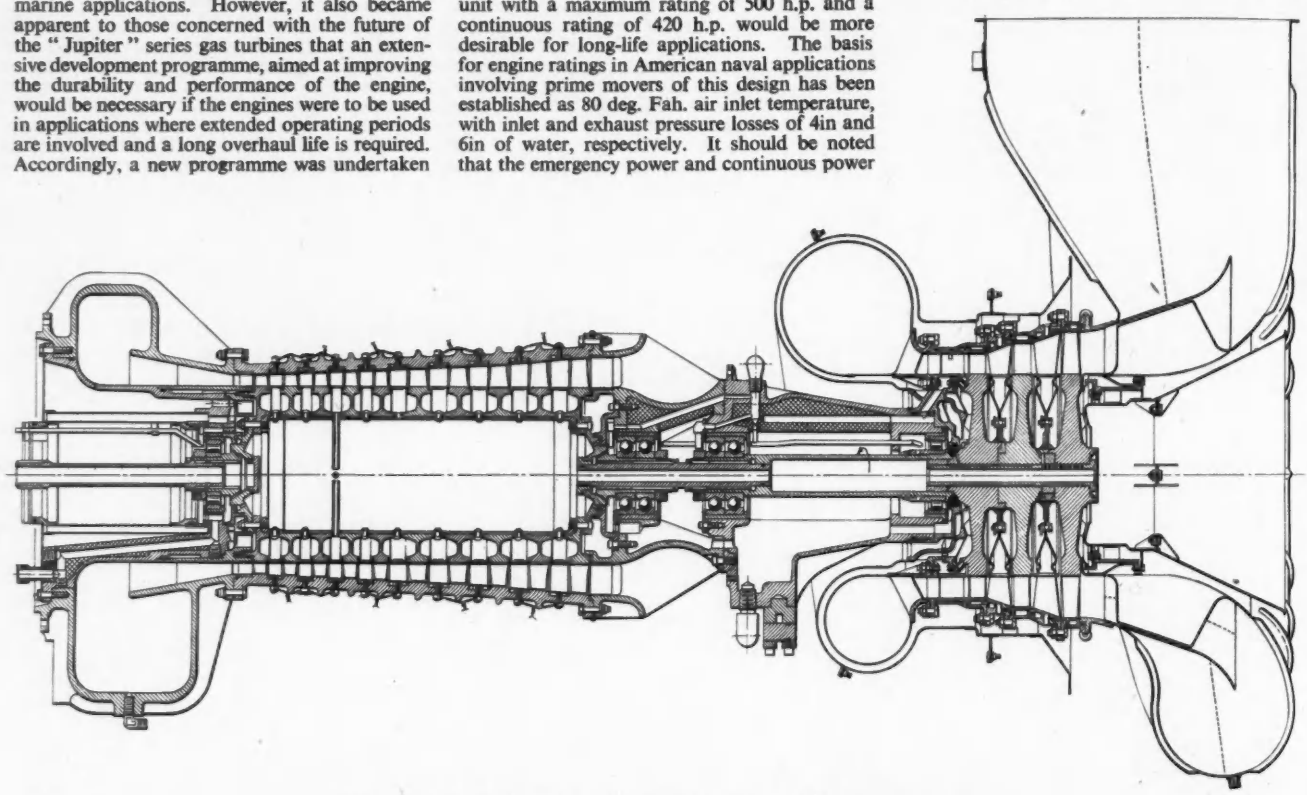


Fig. 1—Cross section of model "T-520J" Solar "Jupiter" gas turbine

blading configuration of the unit does not appear to have compromised the performance of the turbine. A further mechanical feature of the turbine design was that, by substituting various components, the third-stage turbine wheel could be detached from the main rotor assembly and a substitute shorter retaining bolt installed to attach the second-stage wheel to the first-stage rotor assembly. By the addition of a shaft and bearing housing in the exhaust collector attached to the third-stage turbine wheel, the unit could

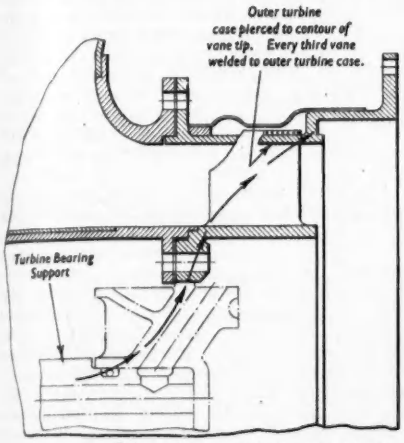

Outer turbine case pierced to contour of vane tip. Every third vane welded to outer turbine case.
Turbine Bearing Support
Turbine casing structural load carried as indicated by arrows.

Fig. 2—Original design of turbine casing and first-stage nozzle

be made into an uncoupled, variable-speed power unit.

A complication entering the design arrangement for the turbine was the problem of providing cooling across the face of the second-stage turbine wheel disc. It may be seen from Fig. 1 that cooling of the first-stage wheel is achieved by inducing air alongside the bearing housing and through a fan machined on the face of the first-stage turbine wheel rotor. The air then circulates around the turbine nozzle scroll shroud, where it achieves some cooling and insulating, and vents to atmosphere. In the case of the third-stage turbine wheel air is again drawn

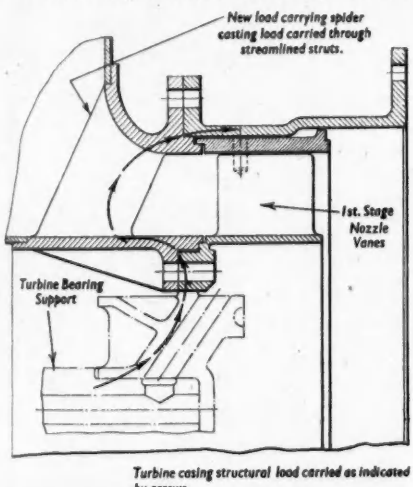

New load carrying spider casting load carried through streamlined struts.
1st. Stage Nozzle Vanes
Turbine Bearing Support
Turbine casing structural load carried as indicated by arrows.

Fig. 3—Redesign of turbine casing with spider casting added ahead of first-stage nozzle

into a fan machined on the back face of the wheel, then is pumped across the wheel, and out through the shroud. To achieve a minimum life of 5000 hours on the turbine wheel, it was essential to provide the second-stage wheel with some form of cooling. Accordingly, in the basic design it was decided to induce air into the compressor-rotor drum by bleeding under the fifth-stage stator shroud ring in the compressor, and leading the air into the compressor drum through holes drilled between the fifth and sixth-stage wheels. The air induced in this manner would then provide pressurisation for the compressor abyrinth oil seals and the turbine labyrinth oil seals, and would be pumped through the hollow shaft of the first-stage turbine wheel through the hollow retaining bolt and out of ¼in diameter holes drilled between the second and third-stage turbine wheels. The pressure of the air induced at the fifth stage of the compressor would be higher than the pressure at the efflux from the second-stage turbine rotor, and would therefore allow the fifth-stage air to perform the cooling function on the second-stage wheel face.

The turbine case support arrangement was redesigned to provide for a radial spline attachment between the first-stage turbine nozzle assembly and the support hub attached to the bearing housing. The outer case arrangement was redesigned to achieve a more satisfactory arrangement to overcome the previous warping and differential expansion characteristics of the prototype turbine case. This incorporated the use of segmented rings over the rotating turbine blades, and radial pin supports for the second and third-stage nozzle vanes. With this basic design configuration, and with modifications made necessary by the increased mass flow to such components as the combustor and the flow passages through the scrolls and exhaust collector, two development engines were built, and the first one commenced test stand operation on August 14, 1952.

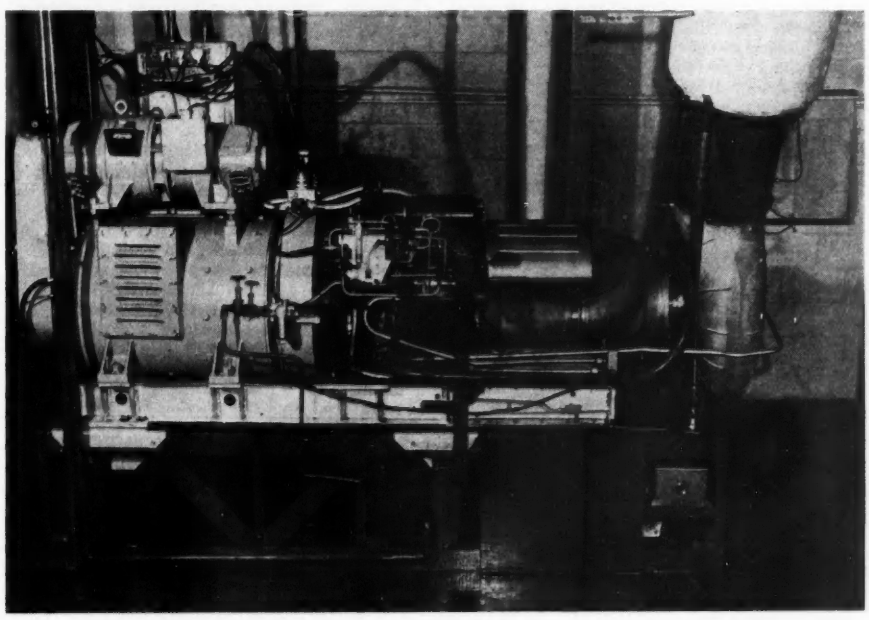


Fig. 4—Gas turbine-electric generating set with " Jupiter " " T-520J " gas turbine acting as prime mover

Performance of Test Engines

Prior to the initial testing of the complete power plant sufficient turbine components became available to enable a rig test of the first-stage turbine rotor nozzle combination, using cold air. The results obtained were quite enlightening. A turbine adiabatic efficiency of 80·6 per cent had been predicted in the design calculations. The stage tests, however, surpassed all predictions and an adiabatic efficiency for the stage was calculated from the test data at 85·6 per cent. While this performance was very gratifying, one disappointing aspect was revealed by the stage test. The relative weight-flow calculation for the nozzle, i.e. the ratio of actual air flow to sonic air flow for a given condition, was approximately 4 per cent high at the design velocity ratio for the stage. From this it appeared that the turbine nozzle efficiency was considerably better than had been estimated ; or that the blockage effect of the turbine rotor blading was considerably less than anticipated. At this point manufacture had proceeded to such an extent that it was not possible to rework the turbine components, and it was decided to assemble the engine with this configuration.

The preliminary tests were short and served as a " shakedown " to evaluate the test stand arrangement and basic mechanical difficulties that usually arise with the initial tests of a prototype engine. In the early stages of testing a number of changes were made to rectify these points. No major mechanical problems were encountered with the unit, and on the very first operation on the test stand the engine was taken to its rated speed of 20,000 r.p.m. and operated there for a period of fifteen minutes without incident. The aerodynamic data obtained in these tests indicated that the design performance of the engine could be attained without difficulty. The redesigned turbine case support arrangement at this period appeared to be holding very well and there were no problems of case warpage or turbine blade tip rubs. On this point the more astute aerodynamicist might infer that the clearances employed are too large and that large quantities of power are being thrown away in poor turbine efficiency. But from a mechanical point of view the company feels gratified not to be bothered with tip rubs.

At this point one serious difficulty arose in the method of cooling the second-stage turbine rotor. As described, it was the intention to induce air into the compressor drum between the fifth and sixth-stage rotor wheels, and to direct the air to pressurise the compressor and turbine labyrinth seals, using the balance of the air after it had flown down the hollow turbine shaft and through the retaining bolt to cool the downstream face of the second-stage turbine wheel. In the early phases of testing it became very clear, however, that this procedure was not taking place. In fact, after installing a static pressure probe and temperature probe through the hollow shaft of the retaining bolt, using a carbon ring for a rotating seal between the probe and the bolt connection, it became apparent that hot gas was flowing back down the face of the second-stage wheel and into the turbine shaft. Upon analysis it appeared that the engine was possibly losing a considerable amount of pressure in bleeding under the stator shroud ring at the fifth stage and entering the holes in the compressor drum. Accordingly, it was decided to block the holes in the compressor drum between the fifth and sixth stages and to move the air bleed by one stage to between the sixth and seventh stages. From data obtained at the pressure taps between the sixth and seventh stages of the compressor and from the static taps in the second and third stages of the turbine, it appeared that sufficient pressure differential existed to allow for substantial pressure loss in entering the compressor drum. Tests made with this arrangement again indicated that the hot gas was flowing back down the face of the

second-stage turbine wheel and into the turbine. At this point it became obvious that the problem of admitting the air into the compressor drum was not going to be cured by the simple expedient of moving the pressure bleed to a higher stage.

In the course of a thorough analysis, the theory was advanced that a vortex existed in the rotating drum and that the bleed air pressure was expended in bucking the pressure gradient of the vortex existing in the drum. To substantiate this theory, the four bleed holes between the sixth and seventh stages of the compressor were enlarged and tapped, and four aluminium tubes were screwed into the inside of the drum. Test results obtained with this arrangement were quite satisfactory. From the pressure and temperature information obtained from the instrumentation installed in the retaining bolt of the turbine, it appeared that cooling air was flowing to the face of the second-stage turbine wheel disc. However, the pressure differential that existed in the bolt when compared with the static pressure at the efflux of the second-stage turbine rotor wheel indicated that the airflow was probably not sufficient to do a satisfactory job of cooling. The test did serve to indicate and substantiate the theory that a vortex existed in the compressor drum, and this was probably the reason for the failure of the original design arrangement. The compressor drum was again modified and the tubes reinstalled between the seventh and eighth stages. Tests made with this arrangement were very satisfactory and temperature-gradient information from the second-stage turbine wheel obtained by the use of thermo-colours indicated that a satisfactory stress life of the second-stage wheel could be obtained with this cooling arrangement.

Most of the problems encountered in the first few hours of operation were annoying and time-consuming, but an event of significance was that after only three hours fifty-two minutes of operating time, during which four disassemblies were made, the engine demonstrated a performance of 520 h.p. on the dynamometer stand. Moreover, after a total of only seven hours of operation, a successful ten-hour endurance run was made at 450 h.p. As operating time on the unit increased, the need for dismantling became less frequent, the periods having first been at every fifty hours of operation, then every 100 hours, then progressing to every 250 hours. The company's engineers became very encouraged with the performance of the unit, both from an

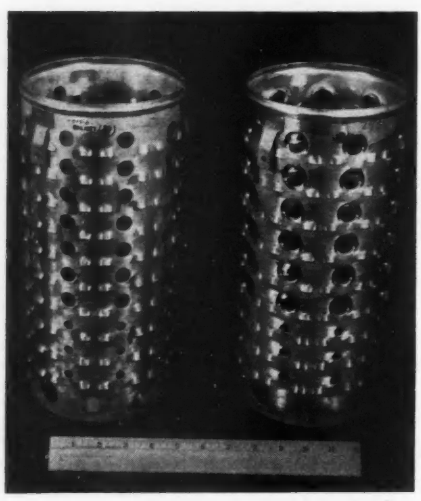


Fig. 5—Original design of combustion liner

aero-thermal and a mechanical point of view. However, at approximately 300 hours of operation the staff began to notice cracking in the outer turbine case in the vicinity which is pierced by the trailing edge of the first-stage nozzle vane, illustrated in Fig. 2. Some axial distortion also was noted in the first-stage nozzle assembly corresponding to the areas of the scroll ahead of the nozzle, which were evidently imposing a

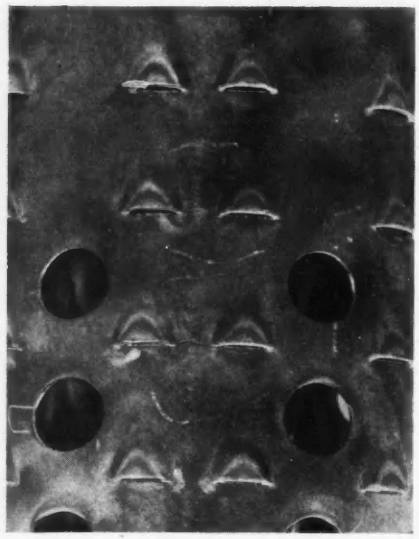


Fig. 6—Failure of combustion liner after cyclic operation of gas turbine

considerable shearing force across the nozzle. The small cracks in the case themselves were not too significant, since they could not progress very far into the turbine case. However, the problem of the yielding of the assembly was of the utmost importance, since, if it continued, the turbine case would become badly misaligned.

This problem was reviewed thoroughly and a redesign was evolved whereby the separating gas loads imposed by the scroll ahead of the turbine were taken through a shell-moulded spider casting welded to the scroll and installed ahead of the first-stage nozzle. To eliminate the cracking in the outer turbine case, the old design case was cut from the existing first-stage nozzle vanes, the vanes turned down and a retaining ring with radial pins installed over the tips, as illustrated in Fig. 3. This meant that support for the outer turbine case was obtained through the spider casting installed ahead of the nozzle vanes, and that the nozzle vanes themselves were free to float under any thermal condition. After a number of tests to determine a satisfactory material and heat-treatment for the cast support, a configuration was obtained which in tests to date has proved very satisfactory, no measurable creep being recorded in one unit after more than 1000 hours of test operation.

In a period of one year from the date of the initial operation of the " T-520 " engine, the firm had attained 1000 hours of test-stand operation, 720 hours of this being attained on one unit. This amounts to approximately 50 per cent availability in a normal working year, and when it is considered that 900 hours of the total time in the first twelve months of operation were obtained in the latter six-month period, the reliability and ruggedness of the two development power plants under evaluation are clearly demonstrated. One aspect of the design of the " T-520J " engine which was thought to be a source of trouble lay in the fact that the three turbine wheels were overhung and, furthermore, that the engine would pass through the first critical speed, calculated to be about 65 per cent of rated speed, during acceleration. It was found during the test programme that this condition presented no problem whatsoever ; in fact, one had to watch the vibration meter very closely for an indication of the critical speed.

In January, 1952, a contract was received from the U.S. Navy Bureau of Ships to develop the model " T-520J " single-shaft unit as a prime mover for a generator set. While the power required in this application was derated from the original design conception, certain aspects of the application were quite rigorous. These included the exclusion of magnetic materials wherever possible in the construction of the engine and gearbox, and a consecutive cyclic load operation. The completed units were to be installed in pairs in an enclosed compartment of a wooden hull vessel. This requirement dictated the use of external shrouding, and since blower cooling was not available for the compartment, an eductor exhaust stack on each unit for the purpose of circulating air through the enclosed engine-room was a requisite.

In this application, the basic " Jupiter " gas turbine was equipped with a 10 : 1 planetary gear reduction and accessory drive gearbox, as illustrated in Fig. 4. The reduction gearbox provides drive pads for the engine accessories, consisting of a conventional 24V aircraft starter ; a speed-sequencing switch used in starting the engine ; a fuel pump governor combination ; a lubricating and scavenge pump, and a tachometer generator. The output of the main shaft of the reduction gearbox was fed into a single-bearing electric generator rated 300kW at 2000 r.p.m. As in all " Jupiter " engines manufactured to date, the starting procedure for the unit was fully automatic.

The development of the gas turbine for this arrangement was quite uneventful, possibly due to the derated power requirement of the application. However, some problems were encountered with the reduction gearbox, mainly attributable to its necessarily unconventional design and the use of non-magnetic material. The main problem encountered was in the design of the planet gear bearings. In the original design of the gearbox the planet gears, which were of an aluminium-bronze alloy, had utilised the gear material as a bearing surface for the planet-carrier journals. From the results of the initial tests with this arrangement, it became obvious that the bearing qualities of the gear material were very poor, resulting in several failures wherein planet gears seized to the shafts on the planet-carrier assembly. The bearing configuration was changed to incorporate a steel-backed babbitt bushing. This modification did

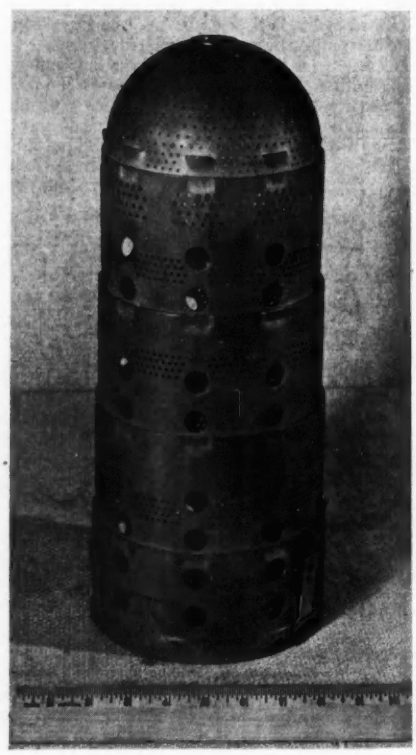


Fig. 7—Redesign of combustion liner using segmental construction

not prove very satisfactory, however. In attempting to minimise the amount of magnetic material used in the gearbox, a stainless steel backing had been used for the bearing outer shell. Since a satisfactory bond could not be obtained between the backing material and the babbitt lining, disintegration of the lining material occurred after a few hours of operation. From the appearance of the failures it was quite evident

that the pinion gear loads were approaching the load limit of a babbitt lining.

With this factor in mind, it was decided to change the bearing lining to a material with a greater load-carrying capacity per unit area. Accordingly, silver-lead-indium-coated bearings were substituted, and the geometrical design of the bearing was changed slightly. The bearing configuration, which had been of the centre oil groove design up to this time, was discarded and a straight-through bushing was used. The oil distribution hole in the journal was moved to a position where the oil entered immediately ahead of the loaded side of the bearing, as near as could be estimated when considering the gear tooth loading and the centrifugal forces on the planet pinion. Since it also was felt that the majority of the damage to the planet pinion gear bearings was incurred during the cold cranking period, it was decided to install a 24V prelubrication pump supplying 10 lb per square inch of oil pressure to the gearbox during the cranking period. To date this redesign has operated very satisfactorily and no evidence of further planet pinion gear bearing failures has been noted.

Apart from minor problems associated with the accessories, which were rectified in the normal course of the development, the only other outstanding mechanical problem encountered during this phase of development was in connection with the combustion chamber liner. The original design of liner, which is illustrated in Fig. 5, was susceptible to cracking in the vicinity of the primary air holes and the cooling louvres. This problem was not encountered until the engine had been operated for some forty to fifty hours under the cyclic load operation (a few seconds at no-load, then a load cycle of a few seconds' duration, and then reverting once more to the no-load condition). Fig. 6 illustrates the kind of failure which would occur during the cyclic operation. Since changes in the material and method of fabrication did little to alleviate the condition, the overall design configuration of the liner was reviewed. On the basis of results obtained in the development of a segmented liner in early tests, it appeared that this method of construction would offer a possible solution. With only minor modifications needed to improve the starting and cooling of the shell in the primary air zone segment, a segmented liner was submitted to a cyclic load endurance test in the engine. The liner is illustrated in Fig. 7. To date, the original liner of this design has operated for approximately 600 hours without incident.

At this point, a prediction of the combustion liner life in the generator application is not possible. A duplicate liner in the second development engine has attained approximately 320 hours of cyclic load operation without sign of failure. Of significance in the application of the gas turbine to cyclic load operation is the fact that in approximately 900 hours of full-load/no-load cyclic load fluctuations, there has been no evidence that this mode of operation has been at all detrimental to the hot parts of the engine. This may be attributed to the fact that the thermal shock conditions imposed on the turbine nozzles and blading are not as severe when using a machine of the power potential of the "T-520J" in this derated application.

Closed-Compartment Operation

To verify the performance of the generator set when installed in the generator compartment of the boat, a mock-up simulating one-half of the generator room was fabricated. The mock-up duplicated the ventilation system and the air inlet and exhaust systems to be used. In this installation, the complete "T-520J" engine was enclosed with aluminium shrouding. The air entrained into the ventilation air intake of the compartment was drawn under the shrouding and through the exhaust stack by the momentum interchange of the stack eductor. The method of applying an exhaust stack eductor for ventilation of an enclosed compartment was developed for a similar installation at the U.S. Navy Engineering Experiment Station in Annapolis, Maryland.

Data obtained over periods sufficient to stabilise the compartment temperature with full load on the generator indicated that the compartment temperature could be maintained at approximately 10 deg. Fah. above the ambient. The ventilation flow through the compartment achieved by the eductor arrangement was approximately 1000 cubic feet per minute. The shrouding system used provided a pleasant-looking enclosure for the complete gas turbine unit, and since the educted air is drawn under the shrouding, it served the purpose of providing a useful safety enclosure for the hot parts of the power plant. The surface temperatures of the shrouding in the vicinity of the turbine were 130 deg. Fah. with the unit operating at full load. From the experience obtained with this installation, it appears that very satisfactory arrangements for the gas turbine engine can be made in enclosed compartments without undue hazard to the operator from contact with high-temperature areas of the engine. In fact, from a personnel point of view, working conditions in the vicinity of the engine during operation in an enclosed space are not at all hazardous, and the noise level is not considered to be unbearable.

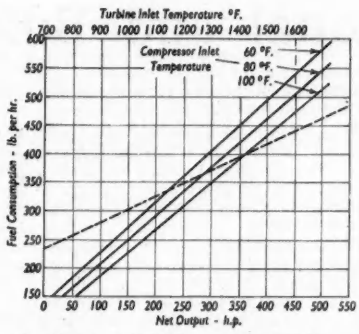


Fig. 8—Model "T-520" constant-speed engine performance at 20,000 r.p.m., corrected to standard sea level conditions with no back pressure

Performance Evaluation

As previously mentioned, stage test performance of the first-stage turbine wheel had indicated that the first-stage nozzle relative weight-flow parameter was approximately 4 per cent high at the design pressure ratio for the stage. Initial performance tests on the engine served to substantiate the results of the initial test. However, the compressor airflow was slightly higher than that originally anticipated from the design calculations. The additional airflow from the compressor was not sufficient to match the turbine flow requirements exactly, and therefore a mismatch existed between the turbine and the compressor. The mismatch was not serious, the engine being able to deliver the desired power rating in the existing condition. This situation was far from ideal, since it meant that the compressor was working at a pressure ratio considerably lower than intended, and also that the turbine was operating at velocity ratios below the design optima at rated speed. Since a redesign of the first-stage nozzle area was quite a costly undertaking, it was decided to proceed in two directions in an attempt to match the compressor and turbine flow requirements. In the case of the compressor, the inlet guide vane was opened 4 deg. from the original value; the first-stage stator, 3 deg., and the second-stage stator 2 deg. The effect of this modification on the engine performance was to increase the compressor airflow approximately 3 per cent at the design speed of 20,000 r.p.m. The increased airflow had a very small effect on the compressor turbine mismatch, the relative weight-flow parameter decreasing approximately 1½ per cent. Possibly the most significant gain from this change was that the rating of the engine with the higher mass flow could be increased approximately 30 h.p.

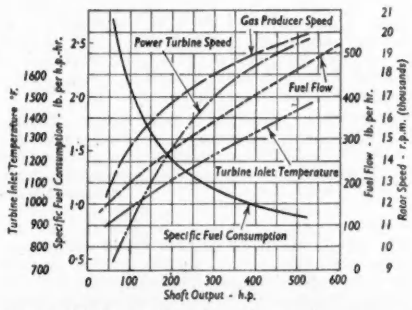

Gas Producer Speed
Power Turbine Speed
Fuel Flow
Turbine Inlet Temperature
Specific Fuel Consumption
Turbine Inlet Temperature °F.
1600 1500 1400 1300 1200 1100 1000 900 800 700
Specific Fuel Consumption - lb. per h.p.-hr.
2·5 2·0 1·5 1·0 0·5
Fuel Flow - lb. per hr.
500 400 300 200 100 0
Rotor Speed - r.p.m. (thousands)
21 20 19 18 17 16 15 14 13 12 11 10 9
0 100 200 300 400 500 600
Shaft Output - h.p.

Fig. 9—Model "T-522" engine performance at optimum power turbine speed, corrected to standard sea level conditions with no back pressure. (Configuration "A")

The second change which had been initiated in an attempt to achieve a closer match between the turbine and compressor flows was the manufacture of a turbine rotor assembly in which all three-stage wheels had been broached with the blading closed 3·5 deg. from the original design. It was felt that this modification, which decreased the effective flow area through the rotors, would also give a slight addition in performance because the rotor stages would be operating with more reaction, and that a slight gain in the adiabatic efficiency of the turbine could be achieved. Results of this test again were not extremely significant. The relative weight-flow parameter from the turbine dropped approximately 1 per cent. However, a gain of about 3 per cent was noted in specific fuel consumption. The performance of the engine when assembled in accordance with this configuration is illustrated in Fig. 8.

A possible reason for this arrangement not demonstrating a more marked increase in performance is poor recovery in the exhaust collector diffuser. The static-to-static pressure efficiency in these tests indicated a value of approximately 33 per cent, compared to a predicted value of 55 per cent. From the results, it would appear that the 3·5 deg. closed rotor in the third stage had changed the efflux angle of the gas leaving the third-stage wheel considerably. With a modification of the design vector diagram to incorporate the 3·5 deg. closed rotor stage, the efflux angle of the gases leaving the turbine would probably be approximately 15 deg. from axial at the design condition. This probably would cause the support struts in the exhaust collector to be stalled, and account for the very poor diffuser efficiency. The original turbine design had been based on a leaving angle from the third-stage rotor very close to axial.

At this point in the aerodynamic development of the unit, sufficient parts became available to modify the turbine into the "T-522" version, the variable-speed split-wheel arrangement of the "Jupiter" engine. Since a number of third-stage turbine nozzles of varying areas had been manufactured for calibration tests of this arrangement, it was decided to continue the turbine development in the "T-522" version of the engine. Performance evaluation was made of the turbine assembled in three different configurations. In each case, a modified compressor with the opened-up inducer and first and second-stage stators was used. The turbine configurations referred to as "A," "B" and "C" were as follows:—

"A"=turbine rotor blades closed 3·5 deg. from original design on rotors 1 and 2; original design angle for the third-stage rotor and for nozzles 1, 2 and 3.

"B"=original design angle on all three rotors and nozzles.

"C"=original design angle on rotors for stages 1, 2 and 3; original design angle on nozzles for stages 1 and 2; the third-stage nozzle closed 2 deg. from the design angle.

From the results obtained in the turbine tests with the engine in this arrangement, it appeared that optimum turbine performance was attained in configuration "A," both with regard to power output and fuel consumption. This performance is illustrated in Fig. 9. The tests substantiated the original design conception in which the multiple-purpose engine for variable-speed applications can be assembled or converted to a unit of single-shaft designs for applications where sudden load changes are liable to occur, such as in generator drive applications.

Tests made with the single-shaft version of the "Jupiter" engine show that design load can be applied or dropped instantly, with fluctuations in the shaft speed of approximately 3 per cent. This is attributable to the high inertia of the single-shaft machine.

Apart from the problems discussed in this article, there have been no mechanical or structural failures of any other component.

Personal and Business

Appointments

LORD MCCORQUODALE OF NEWTON has been appointed a vice-president of the British Employers' Confederation.

MR. STUART MITCHELL, M.I.Mech.E., has been appointed group chief engineer of Associated British Engineering, Ltd.

THE P. AND O. STEAM NAVIGATION COMPANY announces the appointment of Captain G. R. Peters as deputy marine superintendent.

PRIOR STOKERS, Ltd., 1–3, Brandon Road, London, N.7, states that Colonel A. de Chimay, managing director, has been appointed deputy chairman.

WHESSOE, Ltd., Darlington, states that Mr. T. Heslop, secretary, and Mr. M. J. Noone, M.I.Mech.E., manager of operations, have been appointed directors.

COMMANDER (E.) J. A. BLOCKLEY, R.N. ret., has been appointed export sales manager of the Parsons Engineering Company, Ltd., Town Quay Works, Southampton.

MR. I. D. CAMERON and MR. DONALD MCCULLOUGH have been appointed directors of Lumenated Ceilings, Ltd., Alliance House, Caxton Street, London, S.W.1 (telephone, Abbey 7113).

THE BRITISH TANKER COMPANY, Ltd., announces that Mr. J. W. S. Straughan has been appointed chief engineer superintendent of the company in succession to the late Mr. A. Aitken.

MR. A. D. SMART has been appointed secretary of the British Oxygen Company, Ltd., in succession to Mr. H. Coburn, who has become a director and secretary of British Oxygen Gases, Ltd.

MR. N. J. GRIGG has been appointed publicity manager of Horseley Bridge and Thomas Piggott, Ltd., Tipton, Staffs, in succession to Mr. L. R. Parkes, who has joined the publicity staff of A.P.V., Ltd.

JOHNSON AND PHILLIPS, Ltd., Charlton, London, S.E.7, announces the appointment of Mr. W. S. Penn as chief rubber technologist. He succeeds Mr. T. B. Parker, who has retired after fifty-four years' service with the company.

THE BRITISH BROADCASTING CORPORATION announces the appointment of Mr. W. A. Roberts, A.M.I.E.E., as regional engineer, Midland region, in succession to Mr. J. A. Cooper, A.M.I.E.E., who is shortly to retire after thirty-two years' service with the B.B.C.

ROLLS-ROYCE, Ltd., states that Mr. Whitney Straight will join the board on November 1st, and that he will take over the duties of executive vice-chairman from Mr. A. G. Elliott on January 1st next. Mr. Elliott is retiring after forty-three years' service with the company.

MR. WM. C. YOUNG, M.I.C.E., M.I.Mech.E., has been appointed engineer to the Hanningfield Water Joint Managing Committee, which is responsible for the Southend and South Essex Waterworks Companies' joint reservoir scheme at Hanningfield, Essex. Mr. A. L. Davis, A.R.I.C., has been appointed chemist.

METROPOLITAN-VICKERS ELECTRICAL COMPANY, Ltd., Trafford Park, Manchester, has announced the following appointments :—Mr. E. M. Johnson, consultant to the chief electrical engineer ; Mr. C. P. Holder, M.I.E.E., chief engineer, large electrical machine department; Mr. H. I. Wood, A.M.I.E.E., assistant chief engineer, turbo-generator engineering department.

Business Announcements

SERCK RADIATORS, Ltd., and SERCK TUBES, Ltd., have opened new London offices at 16, Berkeley Street, W.1 (telephone, Mayfair 9744).

REDFERN'S RUBBER WORKS, Ltd., states that its subsidiary, Redferns (Bredbury), Ltd., is now trading as a separate entity at Bredbury, near Stockport (telephone, Woodley 2687).

MR. D. J. BOLTON, who recently retired from the Central Electricity Authority, is going to Venezuela, on behalf of Messrs. Kennedy and Donkin, to report on the electricity tariffs of the Caracas undertaking.

THE ABWOOD TOOL AND ENGINEERING COMPANY, Ltd., Dartford, Kent, has been reconstructed and will be known in future as Abwood Machine Tools, Ltd. There is no change in the company's directorate and management.

KESTNER EVAPORATOR AND ENGINEERING COMPANY, Ltd., 5, Grosvenor Gardens, London, S.W.1, states that Mr. Brian N. Reavell, the managing director, has left London for a business tour of the Far East and Australia.

HEAD, WRIGHTSON AND CO., Ltd., announces the formation of the Head Wrightson Export Company, Ltd. Mr. Vaughan Pendred has been appointed managing director of the new company, the London headquarters of which are at 20, Buckingham Gate, S.W.1.

TEDDINGTON AIRCRAFT CONTROLS, Ltd., Cefn Coed, near Merthyr Tydfil, announces an agreement with Giannini, Ltd. (the British affiliate of G.M. Giannini and Co. Inc.), for the manufacture and sale of Giannini pressure transducers, accelerometers and potentiometers.

DIAMOND BLOWER COMPANY, Ltd. states that its factory has been transferred to Wharf Road, Woolston, Southampton (telephone, Southampton 48254 ; telegrams, Flueblower, Southampton). The company's London office is at 26–28, Hallam Street, W.1 (telephone, Langham 5113).

METROPOLITAN-VICKERS ELECTRICAL COMPANY, Ltd., Trafford Park, Manchester, states that its industrial process control engineering department has been transferred to the recently formed electronics department. Mr. R. H. Kelsall is now assistant chief engineer (industrial process control), electronics department.

Contracts

THE GOOLE SHIPBUILDING AND REPAIRING COMPANY, Ltd., has received an order from the Boston Deep Sea Fishing and Ice Company, Ltd., for two diesel-engined trawlers. Each vessel will have the following dimensions : length 130ft, breadth 27ft, depth 13ft 9in, and be fitted with a diesel engine developing 938 b.h.p. at 250 r.p.m., built by Mirrlees, Bickerton and Day, Ltd.

FERRANTI, Ltd., has recently been awarded an order by the Aluminum Company of Canada, Ltd., for three 71MVA, single-phase, generator transformers, stepping up to 301·4kV. These units will form the second 213MVA bank of generator transformers to be supplied by Ferranti, Ltd., for installation in the underground power station of the Alcan project at Kemano, British Columbia. The transformers are unique in that they will have aluminium windings, and it is believed that they will form the largest bank of transformers with aluminium windings in the world.

THE POWER-GAS CORPORATION, Ltd., Stockton-on-Tees, has received an order from Unilever, Ltd., for plant for the production of high-purity hydrogen from propane, using the " Hercules " reforming process. The plant, which will be capable of producing between 16,000 and 22,000 cubic feet of hydrogen per hour, will consist of a reforming furnace, followed by two stages of CO conversion and CO_2 removal and methanation and, in addition, hydrogen compressors, propane and high-pressure hydrogen storage equipment, and a Wiggins gasholder of 7500 cubic feet capacity.

Miscellanea

MR. W. F. PEARCE.—We have learned with regret of the death of Mr. William Findlay Pearce, which occurred at Lupin Lodge, Barnfield, Urmston, Manchester, on October 7th. Mr. Pearce was formerly chief engineer and general manager of the National Boiler and General Insurance Company, Ltd., Manchester.

CABLE SHIP " OCEAN LAYER."—The conversion has been completed of a dry cargo ship, built in 1948, into the single-screw cable ship " Ocean Layer " for Submarine Cables, Ltd. The ship has a length of 378ft, a deadweight of 4800 tons, a service speed of 11 knots and can carry about 2000 miles of deep sea cable. On her maiden voyage the ship will be engaged in laying 67 nautical miles of telephone cable between Norway and Denmark.

STEEL DELEGATION TO RUSSIA.—Last December the Soviet Delegation to the Steel Committee of the Economic Commission for Europe was invited to come to the United Kingdom, and as guests of the steel industry its members visited a number of steel works. The Soviet Ministry of Ferrous Metallurgy recently invited a party of steel experts, who attend meetings of the E.C.E. Steel Committee from the United Kingdom, to visit a number of steel undertakings in the Soviet Union. The United Kingdom Government accepted the invitation and nominated for the visit a team led by Sir Robert Shone, executive member of the Iron and Steel Board. The members of the team are : Mr. C. R. Wheeler, joint managing director, Guest Keen Iron and Steel Company, Ltd.; Mr. W. F. Cartwright, general manager, The Steel Company of Wales, Ltd.; Mr. A. Jackson, director and general works manager, Appleby-Frodingham Steel Company, branch of United Steel Companies, Ltd., and Mr. T. Dennison, technical officer, British Iron and Steel Federation. The delegation returned to this country last week.

GEAR LUBRICATION.—Revol, Ltd., Exchange Buildings, Quayside, Newcastle upon Tyne, 1, manufacturer of " Voler " compound, announces the introduction of a new graphite-base lubricant for exposed gears, known as " Easaply." It is applied straight from the container and sets to its basic heavy viscosity in under ten minutes on moving gears or in thirty to forty minutes on stationary gears. The compound is stated to have a wide range of temperature resistance and to work efficiently without " flow " at temperatures of 160 deg. Fah. and beyond, and give trouble-free running at low temperatures.

AWARDS FOR PAPERS.—The Institution of Engineers and Shipbuilders in Scotland has made the following awards for papers read before the Institution during session 1954–55 : an Institution Medal to Sir William Wallace, C.B.E., F.R.S.E., for his paper entitled " Experiences in the Stabilisation of Ships " ; the W. W. Marriner Premium to Dr. F. T. Barwell, Ph.D., B.Sc. (Eng.), Mr. A. A. Milne, M.A., and Mr. J. S. Webber, B.Sc. (Eng.), for their paper entitled " Some Experiences on Oscillating Bearings " ; an Institution Premium to Mr. G. Johnson, B.Sc., for his paper entitled " Components of the Propulsive Efficiency of Screw Ships " ; an Institution Premium to Professor W. J. Duncan, C.B.E., D.Sc., F.R.S., for his paper entitled " Problems of Stability in Engineering."

DIESEL ENGINE USERS ASSOCIATION.—The annual general meeting of the Diesel Engine Users Association will take place on October 20th at 2 p.m. One item on the agenda is the consideration of a change of title to provide for inclusion of more engineers and others who can further the objects of the Association. The present title was adopted on its formation in 1913. Whilst some members are connected with design, manufacture, installation, and servicing of engines, it is felt that an amended title would make clearer to many, both at home and abroad, the opportunities which this Association affords to participate in its deliberations. This would be in keeping with the way in which this type of prime mover has developed, and the larger membership would enable the Association to serve an even wider field.

THREE INDUSTRIAL FILMS.—Last week the Vacuum Oil Company, Ltd., showed three new industrial films which are the first of a series of such films forming the nucleus of the new European Industrial Film Library. The first film, " Lubricating Greases," illustrates the importance of lubricating greases, gives examples of the different greases in use and stresses the necessity for carefully controlled manufacture. " Cutting Fluids " indicates how to select the correct cutting fluid and how it reduces tool wear and increases cutting speeds. The third film, " Thin Film Lubrication," defines the difference between fluid film and thin film lubrication and explains the reasons for the different properties required by lubricating oils. Each film is 16mm black and white and runs for thirty minutes.

" ENGINEERS IN THE B.B.C."—Careers for graduate engineers and physicists in the B.B.C. form the subject of a booklet " Engineers in the B.B.C.," copies of which can be obtained from the Engineering Establishment Officer, B.B.C., London, W.1. The booklet says that the Engineering Division of the B.B.C. comprises about 4500 staff, of whom about 600 are fully qualified engineers and physicists, and about 2300 are engineers who may not necessarily be fully qualified academically. A number of two-year graduate apprenticeships are awarded annually to engineers and physicists who obtain good honours degrees ; also opportunities for men with a pass degree. The courses for Honours graduates are designed not only to train the young engineer for the B.B.C., but to give him training that will satisfy the Institution of Electrical Engineers, and thus lead to professional status. The course includes a period at the Engineering Training Department, Evesham, six months in the workshops of a large radio manufacturing concern, and some months in two or more of the specialist departments of the B.B.C. Normally, graduate apprentices enter at a salary of £620 a year and after the two-year training course are appointed to a permanent post starting at £725 a year, rising in about five years to £960. The majority get an appointment rising to £1280 after gaining experience in the junior grade, and " there are good prospects of advancement to posts carrying salaries of £1500 a year and upwards."

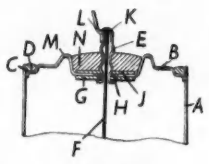
British Patent Specifications

When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. each.

ELECTRICAL ENGINEERING

735,450. October 3, 1952.—AN ELECTRICAL CONDENSER, Standard Telephones and Cables, Ltd., Connaught House, 63, Aldwych, London, W.C.2.

According to the invention an electric wound condenser is arranged in a sealed air-tight container having a cover, part of which is formed into a cup, comprising a bush for an electric connection which is secured to the cover and passes through the cup. The joint by which the bush is secured to the cover is sealed by placing synthetic resin in the cup and around the bush, and then hardening the resin. Referring to the drawing, the condenser container *A* is open at the top, and may be made of cold-sprayed aluminium or of an insulating material such as impregnated paper. The container is closed at the top by a cover *B* made of pressed aluminium sheet. The cover has a step-like depression *C* round its perimeter, so that when it is in place a groove is formed with the upstanding edge of the container, and in this groove hardenable synthetic resin *D* is placed. The resin, preferably hot setting, is chosen so that its setting temperature lies between 120 deg. and 140 deg. Cent., so that the setting occurs during the drying of the encased condenser roll before impregnation. Cold setting resin may, however, be used, if desired. The cover *B* is provided with one or more tubular metal bushes *E*, through which are brought out corresponding connecting wires such as *F* leading to the enclosed condenser roll or rolls. The metal bush *E* is riveted to cover *B* and insulated from it by discs *G*, *H* and *J*. Connection to the outside is obtained through bead *K* and soldering lug *L*. Cover *B* has a raised portion *M*, which surrounds the bush and forms a cup for receiving the synthetic sealing resin *N*. The resins *D* and *N* are both applied and hardened together. A modified arrangement is also shown in the specification.—*August* 24, 1955.

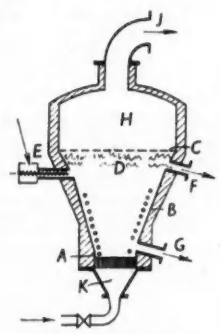


No. 735,450

METALLURGY

736,686. March 20, 1952.—METHOD OF ROASTING SULPHIDIC ORES, Metallgesellschaft Aktiengesellschaft, 45, Bockenheimer, Anlage, Frankfurt-on-the-Main, Germany.

In recent times methods have been proposed for roasting sulphidic ores in which the material to be roasted is treated by an upward current of air in a vigorously agitated ore bed resting on a grate. In such processes it is important that the temperature of the agitated bed should be kept below the temperature of softening or sintering of the material undergoing roasting, since otherwise there is a risk of slagging. The furnace illustrating the invention shown in the drawing, has a height of 3m, the area of the bottom cross-section *A* is 0·25 square metres, and at *B* the cross-section is 0·5 square metres, while at C it is 2 square metres. The limit of the layer is shown at D beneath the cross-section *C*. The material to be roasted is introduced by a conveyor worm *E*, and the roasted material is removed through the openings shown at *F* and *G*. Above the widening part there is a further short and even, widened shaft *H*, of constant cross-section which leads to a gas outlet *J*. The roasting gas, for example, air, is blown into the reaction chamber from a wind box *K* through a nozzle-plate. Inside the furnace at its side walls cooling pipe coils are provided. In some of these cooling coils there flows gas or vapour which serves as the cooling medium; other coils carry a liquid cooling medium such as water or a salt melt, molten metal or high-boiling oil, or other compound which is capable of being heated to a high temperature without setting up a substantial vapour pressure. An example of the roasting of zinc blende, copper ore and pyrrhotite, is also included in the specification. *September* 14, 1955.

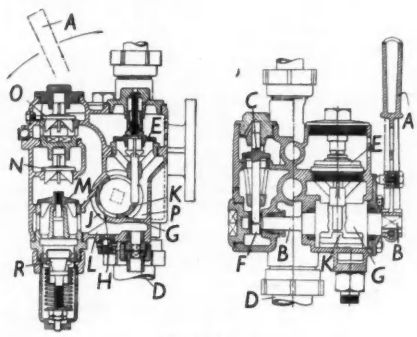


No. 736,686

RAILWAY ENGINEERING

736,377. June 15, 1953.—VACUUM BRAKE EJECTORS, Gresham and Craven, Ltd., Ordsall Lane, 5, Lancashire. (*Inventor: Gerald Cranton Marsh.*)

The object of this invention is to provide an improved and simplified arrangement for operating the air valve, and for isolating the connection between that valve and the train pipe from the connection to the ejector nozzles. As shown in the drawing, the injector has a handle *A* mounted on the spindle *B*, which operates the steam valve *C* by which steam is supplied to the ejector for producing a vacuum in the pipe *D* leading to the brake cylinders. It also operates the air admission valve *E* by which air is admitted to the pipe *D* to destroy the vacuum. The valve *C* is operated by a cam *F* on the spindle *B* and the valve *E* is operated by the rotary member *G* on the spindle which has a gap in its periphery at *H* to form a port, which can be brought into and out of coincidence with a port *J* in the part of the casing in which the rotary member *G* turns, and also a further gap the end of which can be brought to abut against, and raise the stem of the valve *E*, against the pressure of the spring in order to open the valve. When the valve *E* is opened by turning the spindle *B* and the rotary member *G* to a position in which the part *K* engages the stem of the valve *E*, the port *H* is moved into such a position that it is out of coincidence with the port *J*. The ejector nozzles, the small continuously working ejector and the main ejector, controlled by the valve *C*, exhaust the space *L* through the valves *M*, *N* and *O* in the usual way, this space connecting with the train pipe *D* by way of the ports *H* and *J*. When the rotary member *G* opens the valve *E* to admit air to the space *P* and the train pipe *D*, it automatically cuts off communication between the vacuum space *L* and the train pipe *D*. Likewise, when the valve *E* is closed the rotary member *G* is in the position shown and establishes communication between the vacuum space *L* and the train pipe so that a vacuum can be created by the small continuously working ejector drawing through the valve *O* or by both ejectors drawing through the valves *O* and *N*. The valve *R* is opened to admit air to the space *L* if the vacuum in it becomes excessive.—*September* 7, 1955.

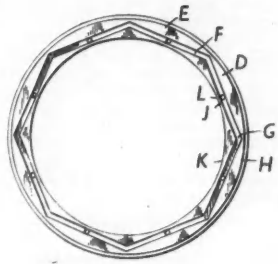


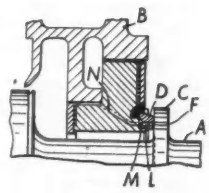
No. 736,377

POWER TRANSMISSION

736,568. June 16, 1953.—GAS SEALS BETWEEN RELATIVELY ROTATABLE PARTS, D. Napier and Son, Ltd., 211, Acton Vale, London, W.3. (*Inventor: Joseph Dudley Shuldham de Guerin.*)

The invention relates to gas seals for reducing or preventing the escape of gas between two relatively rotatable parts, such as a shaft with a liquid sealing film between two adjacent annular sealing surfaces which lie face to face. In the construction shown in the drawing, a gas seal is provided between a rotating shaft *A* and a housing *B* and the shaft is provided with a radial flange *C*, one face of which is machined accurately flat to constitute a sealing surface which co-operates with an annular sealing member *D* supported from the housing *B*. The face *E* of the annular sealing member which co-operates with the flange *C* is machined accurately flat and has formed on its surface a shallow groove *F* which, when seen in the direction of the axis of the shaft, is in the form of a regular octagon. As illustrated, the corners *G* of the octagon lie adjacent to the outer periphery *H* of the sealing member while the mid-points *J* of the sides of the octagon lie adjacent the inner circumference *K*. A series of bores *L* parallel to the axis of the shaft are formed in the sealing member communicating with the mid-points of each side of the octagonal distributing groove *F* and with an annular liquid supply gallery *M* to which sealing liquid is delivered under pressure through one or more supply ducts *N*.—*September* 7, 1955.



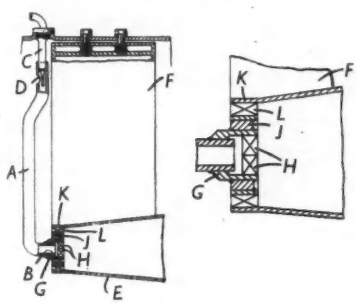


No. 736,568

GAS TURBINES

723,830. *Amended.* September 13, 1952.—FLAME STABILISING DEVICE, Armstrong Siddeley Motors, Ltd., Parkside, Coventry. (*Inventor: Sidney Allen.*)

The invention relates to a flame stabilising device for providing a pilot flame in a jet-propulsion pipe in which fuel has to be burned in a high velocity gas stream in an afterburning or exhaust reheat system for a gas-turbine jet-propulsion unit. The main object of the invention is to provide an improved flame stabiliser which will enable combustion to be accelerated and completed within the stabiliser casing and which will be efficient at any altitude. In the construction shown in the drawing, use is made of a transversely extending tube *A*, the radially inner end *B* of which is coaxial with the stabiliser casing and coacts with the upstream end of the casing. A nozzle or spraying device *C* for the fuel for the pilot flame extends radially through the wall of the jet pipe into the adjacent open end of the transverse tube *A*. On the upstream side of the tube in the vicinity of the fuel nozzle is provided an inlet opening *D* which is capable of taking in sufficient gaseous fluid from the interior of the jet pipe to vaporise, in conjunction with the external heating of the tube *A*, the fuel before it enters the stabiliser casing, so that the fuel will not be carbonised in the tube but will be in a condition for immediate ignition in the casing *E*. The transverse tube *A* is arranged just upstream of the supporting strut *F*, so that it will introduce relatively little additional frictional drag. In the construction shown in the right-hand view, the end *B* of the fuel supply tube is welded to a sleeve portion *G* which supports swirl vanes *H*. The sleeve is in turn carried by an annulus *J* from a cylindrical portion *K* of the stabiliser casing through vanes *L* which introduce a swirl in the gaseous fluid in the opposite direction to that of the vanes *H*. Three further modifications in design are also shown in the specification.—*August* 31, 1955.



No. 723,830

Launches and Trial Trips

WESTERN GULF, oil tanker; built by the Netherlands Dock and Shipbuilding Company for the Afran Transport Company; length overall 695ft, length between perpendiculars 660ft, breadth moulded 90ft 6in, depth 48ft, displacement 48,325 tons, deadweight 37,000 tons, draught 36ft, speed 15·9 knots; steam deck machinery, four 1035 tons per hour turbine-driven centrifugal cargo oil pumps, two 150 tons per hour stripping pumps; two 550kW turbine-driven alternators; one set of N.D.S.M.-Parsons double reduction geared turbines, 13,750 s.h.p. at 108 propeller revolutions per minute, two N.D.S.M.-Babcock-Wilcox boilers, superheated steam at 600 lb per square inch gauge and 800 deg. Fah.—Launch, September 3rd.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

BRITISH INSTITUTION OF RADIO ENGINEERS

Wed., Oct. 26th.—LONDON SECTION: School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, W.C.1, Annual General Meeting, 6 p.m. "Recent Advances in Microwave Tubes," R. Kompfner, 7 p.m.

CEMENT AND CONCRETE ASSOCIATION

Tues., Oct. 25th.—College of Technology, Anglesey Road, Portsmouth, "Concrete Placing and Formwork," A. B. Harman, 7 p.m.——Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough, "Lightweight Concrete," H. A. Hodson, 7 p.m.

CHADWICK PUBLIC LECTURE

Tues., October 25th.—Lecture Theatre, Department of Civil and Municipal Engineering, University College, Gower Street, London, W.C.1, "Development of the Measurement of Strains in Structures," R. J. Wilkins, 5.30 p.m.

CHEMICAL SOCIETY

Wed., Oct. 19th.—BRISTOL BRANCH: Technical College, Brunswick Road, Gloucester, "Some Newer Plastic Materials," E. M. Evans, 6.30 p.m.

Thurs., Oct. 20th.—LONDON BRANCH: Institution of Civil Engineers, Great George Street, Westminster, S.W.1, "The Photosynthetic Carbon Cycle," M. Calvin, 7.30 p.m.

COMBUSTION ENGINEERING ASSOCIATION

To-day, Oct. 14th.—Conference Room, Campfield Avenue, Deansgate, Manchester. In connection with the Fuel Efficiency Exhibition (Wed., Oct. 12th, to Sat., Oct. 22nd) the Association has arranged a Conference entitled "The Cost of Steam."

DIESEL ENGINE USERS ASSOCIATION

Thurs., Oct. 20th.—ANNUAL GENERAL MEETING: Caxton Hall, Westminster, London, S.W.1, Report for 1954; "Diesel Engines: Design for Service," C. H. Bradbury, 2 p.m.

ENGINEERING INDUSTRIES ASSOCIATION

To-day, Oct. 14th.—Royal Horticultural Society's New Hall, Greycoat Street, London, S.W.1, Eighth London Regional Display.

ILLUMINATING ENGINEERING SOCIETY

Tues., Oct. 18th.—LIVERPOOL CENTRE: Liverpool Engineering Society, 9, The Temple, 24, Dale Street, Liverpool, Chairman's Address, G. L. Butler, 6 p.m.

Wed., Oct. 19th.—TEES-SIDE GROUP: Cleveland Scientific and Technical Institute, Corporation Road, Middlesbrough, "The Application and Maintenance of Discharge Lamp Installations," J. J. French, 6.30 p.m.

Mon., Oct. 24th.—LEEDS CENTRE: E.L.M.A. Lighting Service Bureau, 24, Aire Street, Leeds, 1, Chairman's Address, "The Installation, the Engineer and the Local Authority," R. R. Cooper, 6.15 p.m.

Tues., Oct. 25th.—LONDON CENTRE: Lighting Service Bureau, 2, Savoy Hill, W.C.2, Report and Discussion on the 1955 Meeting of the International Commission on Illumination, 6 p.m.

Wed., Oct. 26th.—TRANSVAAL CENTRE: Room 95, Public Library, Johannesburg, Annual General Meeting, 8 p.m.

INCORPORATED PLANT ENGINEERS

To-day, Oct. 14th.—BIRMINGHAM BRANCH: Imperial Hotel, Temple Street, Birmingham. MOBILE PLANT DISCUSSION GROUP: Films, "Care and Maintenance of Plant," "Aveling Barford Dumper Grader,"; paper by P. Stevenson, 7.30 p.m.

Wed., Oct. 19th.—KENT BRANCH: Bull Hotel, Rochester, "Selection of Electric Motors for Industrial Purposes," J. M. Peel, 7 p.m.

Thurs., Oct. 20th.—BLACKBURN BRANCH: Golden Lion Hotel, Blackburn, "The Repair of Fractured Castings," N. Tinwell, 7.30 p.m.——LONDON BRANCH: College of Preceptors, Bloomsbury Square, W.C.1, "The 1400 Excavator," C. McL. Cameron, 7 p.m.

Tues., Oct. 25th.—S. WALES BRANCH: S. Wales Engineers Institute, Park Place, Cardiff, "Safety in Industry," F. W. Thompson, 7.15 p.m.

Thurs., Oct. 27th.—SHEFFIELD AND DISTRICT BRANCH: Grand Hotel, Sheffield, "Dust Generation and Control in Foundries," W. H. White, 7.30 p.m.

INSTITUTE OF BRITISH FOUNDRYMEN

Tues., Oct. 18th.—E. ANGLIAN SECTION: Central Hall, Public Library, Ipswich, Induction of President, W. E. Cates, 7.30 p.m.

Wed., Oct. 26th.—LONDON BRANCH: Waldorf Hotel, Aldwych, W.C.2, "Co-operation Between Engineer and Founder on Casting Design," G. Blanc and M. Jaumain, 7.30 p.m.

Thurs., Oct. 27th.—SOUTHAMPTON SECTION: Technical College, St. Mary's Street, Southampton, "Metal Melting Furnaces and Hot-Blast Cupolas," F. C. Evans, 7.30 p.m.

INSTITUTE OF FUEL

To-day, Oct. 14th.—SCOTTISH SECTION: Royal Technical College, Glasgow, "Development of Slurry Handling Plant at Barony Power Station," J. R. Croucher, 7 p.m.

Thurs., Oct. 20th.—N.W. SECTION: Engineers' Club, Albert Square, Manchester, "Coal Preparation and Evaluation," J. K. Mattnews, 7 p.m.

Wed., Oct. 26th.—MERSEYSIDE SUB-SECTION: Liverpool Engineering Society, 9, The Temple, Dale Street, Liverpool, "Some Factors Governing the Welfare of Steam Boilers and Other Pressure Plant," F. Shapley, 6 p.m.

Thurs., Oct. 27th.—E. MIDLAND SECTION: Lecture Theatre, Gas Showrooms, Nottingham. Open Forum to discuss "Mineral Matter in Coal: Its Importance and Implication," 6.15 p.m. ——MIDLAND SECTION: James Watt Memorial Institute, Great Charles Street, Birmingham, 3, "The Impact of Refractory Materials on the Efficient Use of Fuel," A. T. Green, 6 p.m.

INSTITUTE OF MARINE ENGINEERS

Mon., Oct. 17th.—STUDENT MEETING: 85, Minories, London, E.C.3, Films, including "The Sea Shall Test Her," 6.30 p.m.

Wed., Oct. 19th.—MERSEYSIDE AND N.W. SECTION: JUNIOR LECTURE: Riversdale Technical College, Liverpool, "Launching of Ships," R. S. Hogg, 5.30 p.m.

Thurs., Oct. 20th.—N.E. COAST SECTION: Stephenson Buildings, King's College, Claremont Road, Newcastle upon Tyne, "Practical Approach to Some Vibration and Machinery Problems in Ships," T. W. Bunyan, 6.15 p.m.

Wed., Oct. 26th.—SCOTTISH SECTION: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, C.2, "Watchkeeping and Seagoing Practice," H. C. Gibson, 7.30 p.m.

Thurs., Oct. 27th.—KINGSTON UPON HULL AND E. MIDLANDS SECTION: Royal Station Hotel, Kingston upon Hull, "Marine Diesels—Their Production and Applications," G. K. Baguley 7.30 p.m.

INSTITUTE OF NAVIGATION

Wed., Oct. 19th.—Royal Geographical Society, 1, Kensington Gore, London, S.W.7, Annual General Meeting. Presidential Address, "The Place of Astronomy in Navigation," 2.45 p.m.

Mon., Oct. 24th.—Royal Geographical Society, 1, Kensington Gore, London, S.W.7, "Off the Beaten Track: From Instinct Through Art to Science," a lecture to cadets from Nautical Schools, open to members, 2.15 p.m.

INSTITUTE OF PETROLEUM

Wed., Oct. 19th.—STANLOW BRANCH: Grosvenor Hotel, Chester, "Gasification of Fuel Oil," F. H. Garner and R. Long, 7.30 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

To-day, Oct. 14th.—S. WALES GROUP: S. Wales Institute of Engineers, Park Place, Cardiff, "Metal Spraying and Reclamation," Lloyd Manuel, 7 p.m.

Mon., Oct. 17th.—SCOTTISH CENTRE: North British Hotel, Edinburgh, "Clutch and Brake Linings," L. P. Godfrey, 7.30 p.m.

Thurs., Oct. 20th.—LONDON CENTRE: Royal Society of Arts, John Adam Street, Adelphi, W.C.2, "Mechanical Handling Equipment in Relation to Commercial Road Transport," C. S. Shaw, 6.30 p.m.——YORKSHIRE CENTRE: Great Northern Hotel, Wellington Street, Leeds, 1, "The Use of Fibre Glass and Polyester Resins on Public Service and Commercial Vehicles," B. S. Parkyn, 7.30 p.m.

Tues., Oct. 25th.—N.E. CENTRE: Three Tuns Hotel, Durham, "Some Aspects of Vehicle Insurance and Accident Assessment," C. W. Duffie, 7 p.m.

INSTITUTE OF WELDING

Wed., Oct. 26th.—N. LONDON BRANCH: Manson House, Portland Place, W.1, "The Part of Resistance Welding in Automation," R. W. Ayers, 7 p.m.

INSTITUTION OF CHEMICAL ENGINEERS

Sat., Oct. 15th.—MIDLANDS BRANCH: The University, Nottingham, "The Mechanism of Operation of Bubble Cap Plates," F. H. Garner, 3 p.m.

INSTITUTION OF CIVIL ENGINEERS

Tues., Oct. 18th.—RAILWAY MEETING: Great George Street, Westminster, London, S.W.1, "Uses of Aerated Cement Grout and Mortar in Stabilisation of Slips, Large-Scale Tunnel Repairs, and Other Works," M. C. Purbrick and D. J. Ayres, 5.30 p.m.

Fri., Oct. 21st.—Great George Street, Westminster, London, S.W.1, Graduates and Students Conversazione, 7.30 to 11 p.m.

Tues., Oct. 25th.—HYDRAULICS MEETING: Great George Street, Westminster, London, S.W.1, "Experiments with Hydraulic Models of Port Lyttelton in New Zealand," R. C. H. Russell, 5.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Mon., Oct. 17th.—INFORMAL MEETING: Savoy Place, Loudon, W.C.2, Discussion on "Railway Signalling," opened by J. H. Fraser, 5.30 p.m.

Tues., Oct. 18th.—EDUCATION DISCUSSION CIRCLE: Savoy Place, London, W.C.2, Discussion on "Analogues and Equivalent Circuits," opened by W. A. Turner, 6 p.m.——LONDON GRADUATES' AND STUDENTS' SECTION: R.E.M.E. Training Centre, Bailleul Barracks, Arborfield, Berks, Chairman's Address, "A.C. Switchgear," M. H. F. Collins, 7 p.m.—— S.E. SCOTLAND SUB-CENTRE: Heriot-Watt College, Chambers Street, Edinburgh, "Thermionic Valves of Improved Quality for Government and Industrial Purposes," E. G. Rowe, P. Welch and W. W. Wright, 7 p.m.——N. MIDLAND CENTRE, UTILIZATION GROUP: Central Electricity Authority, 1, Whitehall Road, Leeds, "Design, Performance and Application of Miniature Circuit Breakers," H. W. Wolff and T. G. F. Atherton, 6.30 p.m.

Wed., Oct. 19th.—RADIO AND TELECOMMUNICATION SECTION: Savoy Place, London, W.C.2, Chairman's Address, H. Stanesby, 5.30 p.m.——LONDON GRADUATES' AND STUDENTS' SECTION: Visit to Foster Transformers, Ltd., South Wimbledon, 2.15 p.m.

Tues., Oct. 25th.—MEASUREMENT AND CONTROL SECTION: Savoy Place, London, W.C.2, "An Electronic Particle Accelerator," D. R. Chick and D. P. R. Petrie; "An Electrostatic Analyser for the Absolute Measurement of Proton Energies and the Establishment of Fixed Points on the High-Voltage Scale," S. E. Hunt, D. P. R. Petrie, K. Firth, and A. J. Trott, 5.30 p.m.

INSTITUTION OF ENGINEERING INSPECTION

Mon., Oct. 17th.—E. SCOTLAND BRANCH: Royal British Hotel, Dundee, "Production and Inspection of Torpedo Mechanism," B. G. York, 7.30 p.m.

Mon., Oct. 24th.—WOLVERHAMPTON BRANCH: Mander Bros., Ltd., Wolverhampton, Works Visit; "Industrial Paints," W. A. Edwards, 7.15 p.m.

Thurs., Oct. 27th.—N.W. BRANCH: Engineers' Club, Albert Square, Manchester, "The Application of Small Gas Turbines to Road Transport," P. A. Phillips, 7.30 p.m.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND

Tues., Oct. 18th.—GENERAL MEETING: 39, Elmbank Crescent, Glasgow, "Resistance Experiments on an 18ft Plank," J. F. Allan and R. S. Cutland, 7.30 p.m.

INSTITUTION OF HEATING AND VENTILATING ENGINEERS

Tues., Oct. 25th.—SCOTTISH BRANCH: Building Centre, 425, Sauchiehall Street, Glasgow, C2, "Meteorological Data and Design Temperatures," H. C. Jamieson, 7 p.m

INSTITUTION OF HIGHWAY ENGINEERS

To-day, Oct. 14th.—N.E. BRANCH: Visit to the Concrete Works of Tyzack and Co., Ltd., Fulwell Road, Monkwearmouth, Sunderland, 12.30 p.m.

INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

Wed., Oct. 19th.—INFORMAL MEETING: Conference Room, 4th Floor, Waterloo Bridge House, London, S.E.1, "What Makes an Engineer?" Discussion to be opened by J. G. Straw, 5 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

Mon., Oct. 17th.—SCOTTISH A.D. CENTRES: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, Address by the A.D. Chairman-Elect., C. G. Williams, 7.30 p.m.

Tues., Oct. 18th.—N.W. GRADUATES' SECTION: Engineers' Club, Albert Square, Manchester, "Industrial Training, with Particular Reference to Atomic Energy Factories," K. J. Frost, 6.30 p.m.

Wed., Oct. 19th.—N.E. A.D. CENTRE: Chemistry Lecture Theatre, The University, Leeds, "Disc Brakes," F. G. Parnell and F. J. Bradbury, 7.30 p.m.——COVENTRY GRADUATES' SECTION: Craven Arms Hotel, High Street, Coventry, "Space Flight," F. Shaw, 7.30 p.m.——SOUTHERN GRADUATES' SECTION: Polygon Hotel, Southampton, Chairman's Address, "Internal Combustion Engines Applied to Marine Craft," K. Roberts, 7.30 p.m.

Thurs., Oct. 20th.—INDUSTRIAL ADMINISTRATION AND ENGINEERING PRODUCTION GROUP: Engineers' Club, Albert Square, Manchester, "The Development and Scope of Work Study," R. M. Currie, 6.45 p.m.

Fri., Oct. 21st.—GENERAL MEETING: 1, Birdcage Walk, Westminster, London, S.W.1, Presidential Address, P. L. Jones, 5.30 p.m.

INSTITUTION OF MINING AND METALLURGY

Thurs., Oct. 20th.—GENERAL MEETING: Geological Society of London, Burlington House, Piccadilly, London, W.1, Papers for Discussion, "Research as a Business Enterprise," F. H. Chapman; "Pressure Manifestations at Great Mining Depths on the Witwatersrand," J. F. G. R. Heywood, 5 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

To-day, Oct. 14th.—E. COUNTIES SECTION: Davey Paxman and Co., Ltd., Britannia Works Canteen, Colchester, "Ball and Roller Bearings Including their Application and Manufacture," A. R. Watson, 7.30 p.m.

Mon., Oct. 17th.—DERBY SECTION: College of Art, Derby, "Automatic Mechanical Project Factory," H. J. Graves, 7 p.m.——N.E.SECTION: Neville Hall, Newcastle upon Tyne, "Work Study as Applied to Engineering Operations," H. E. North, 7 p.m.

Tues., Oct. 18th.—COVENTRY SECTION: Craven Arms, High Street, Coventry, "Bridging the Handling Gap," J. Bright, 7 p.m.

Wed., Oct. 19th.—BIRMINGHAM SECTION: James Watt Memorial Institute, Great Charles Street, Birmingham, "The Application of Electronics to Industry," J. B. C. Robinson, 7 p.m.—— WOLVERHAMPTON SECTION: Technical College, Wolverhampton, "Plant Maintenance and Productivity," R. A. Rogers, 7.15 p.m.——PRESTON SECTION: Lecture Hall, Public Halls, Blackburn, "Productivity in Good Times and Ill," M. Lewis Wright, 7.30 p.m.

Thurs., Oct. 20th.—GLASGOW SECTION: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Unusual Products that Can Be Made from Tube," A. N. Attwood, 7.30 p.m.——SOUTHERN BRANCH: Polygoo Hotel, Southampton, "Gas Turbines—Basic Principles and Production Problems," C. E. Wurr, 7.15 p.m.

Mon., Oct. 24th.—MANCHESTER SECTION: Reynolds Hall, College of Technology, Manchester, "Cutting Tools—Application and Research," M. O. Short, 7.15 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

Wed., Oct. 19th.—YORKSHIRE BRANCH: Great Northern Hotel, Leeds, Chairman's Address, R. H. Evans, 6.30 p.m.

Thurs., Oct. 20th.—LANCASHIRE AND CHESHIRE BRANCH: College of Technology, Mancnester, Chairman's Address, J. M. Morris, 7.15 p.m.

Tues., Oct. 25th.—WALES AND MONMOUTHSHIRE BRANCH: Mackworth Hotel, Swansea, "Recent Trends in the Design of Industrial Buildings," A. V. Hooker, 6.30 p.m.

IRON AND STEEL INSTITUTE

To-day, Oct. 14th.—Special Meeting in Scunthorpe.

Mon., Oct. 17th.—HALFIELD MEMORIAL LECTURE: Firth Hall, The University, Sheffield, "Trends in Metallurgical Research in the United States," E. C. Bain, 6.30 p.m.

Thurs., Oct. 20th.—IRON AND STEEL ENGINEERS' GROUP: Engineers' Club, Albert Square, Manchester. Half-day meeting in connection with the National Fuel Efficiency Exhibition; "Fuel Efficiency in the Iron and Steel Industry," W. S. Walker, 10.30 a.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, Oct. 14th.—ORDINARY MEETING: Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "Some Interesting Axial-Flow Fan Applications," R. C. Dick, 7 p.m.

Fri., Oct. 21st.—INFORMAL MEETING: Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "The Atom," S. A. McAuliffe, 7 p.m.

MANCHESTER ASSOCIATION OF ENGINEERS

Tues., Oct. 18th.—JOINT MEETING WITH THE INSTITUTE OF PETROLEUM: Engineers' Club, Albert Square, Manchester, "Magnetic Particle and Penetrant Methods of Non-destructive Testing of Materials," R. Schnurmann, 6.45 p.m.

NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

To-day, Oct. 14th.—OPENING GENERAL MEETING: Lecture Theatre, Literary and Philosophical Society, Newcastle upon Tyne, "The Impact of the Development of Atomic and Thermonuclear Weapons on the Royal Navy," J. R. H. Bull, 6.15 p.m.

ROYAL INSTITUTION OF CHARTERED SURVEYORS

Tues., Oct. 18th.—LAND SURVEYORS' GENERAL MEETING: 12, Great George Street, Westminster, London, S.W.1, "Photogrammetric Plotting Machines: An Historical Review of Their Development," E. A. Miskin, 5.30 p.m.

Wed., Oct. 19th.—GENERAL MEETING OF QUANTITY SURVEYORS: 12, Great George Street, Westminster, London, S.W.1, "The R.I.B.A. Form of Contract: Some Legal Aspects," J. Stuart Daniel, 6 p.m.

ROYAL SOCIETY FOR THE PROMOTION OF HEALTH

Mon., Oct. 17th.—LONDON SESSIONAL MEETING: Caxton Hall, Caxton Street, Westminster, S.W.1, Discussion on "The Clean Air Bill," opening speakers Sir Hugh Beaver and J. A. Scott, 2.30 p.m.

SHEFFIELD METALLURGICAL ASSOCIATION

Tues., Oct. 18th.—B.I.S.R.A. Laboratories, Hoyle Street, Sheffield, 3, "Ultra-High Tensile Strength Steels," K. J. Irvine, 7 p.m.

SHEFFIELD SOCIETY OF ENGINEERS AND METALLURGISTS

Mon., Oct. 17th.—HATFIELD MEMORIAL LECTURE: Firth Hall, The University, Western Bank, Sheffield, "Trends in Metallurgical Research in the United States," Edgar C. Bain, 6.30 p.m.

SOCIETE DES INGENIEURS CIVILS DE FRANCE

Mon., Oct. 17th.—BRITISH SECTION: Institution of Civil Engineers, Great George Street, Westminster, London, S.W.1, "The Reconstruction of the Swing Span of the Caronte Viaduct," M. Lucien Carpentier, 5.30 p.m.

WEST OF SCOTLAND IRON AND STEEL INSTITUTE

Fri., Oct. 21st.—39, Elmbank Crescent, Glasgow, C.2, Presidential Address, S. Thomson, 6.45 p.m.